Registration

Please proceed the application form from the homepage of the following URLvia the Apollon System.

-http://swim.taiiku.tsukuba.ac.jp/asa/

Fees

(Please refer to home page)

	dead line	Price	Contents
Not Student	～2007.12.31	¥40,000	Admission to scientific programme, social programme and conference materials. (Farewell dinner and excursion is not included in student's fee)
	～2008.3.7	¥50,000	
Student	～2007.12.31	¥20,000	
	～2008.3.7	¥30,000	

Fees of ASA is included in the Fees of Japanese Session.

Only for Japanese Session, the fees is ￥5,000 (Student;￥3,000).

Application of presentaion

Deadline of Abstract：**2007.12.15 (Sat)**

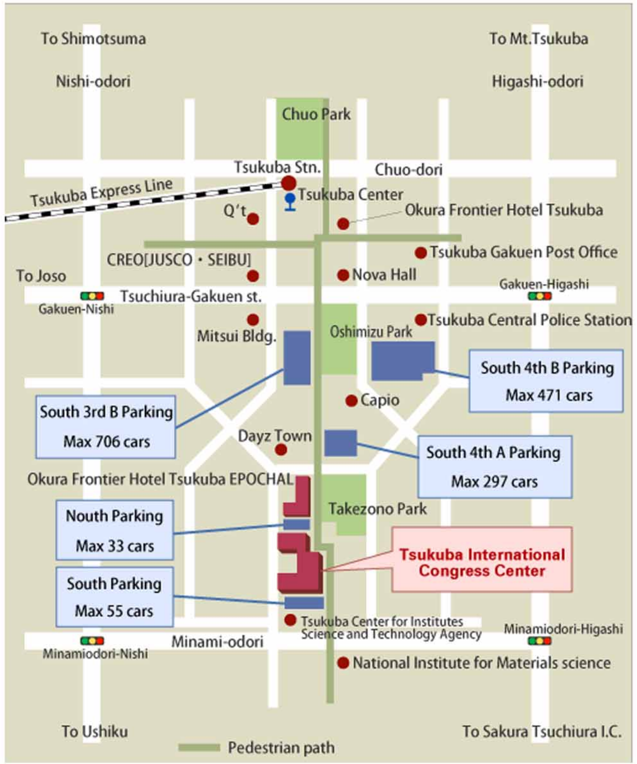
Deadline of full manuscript：**2008.1.15 (Tue)**

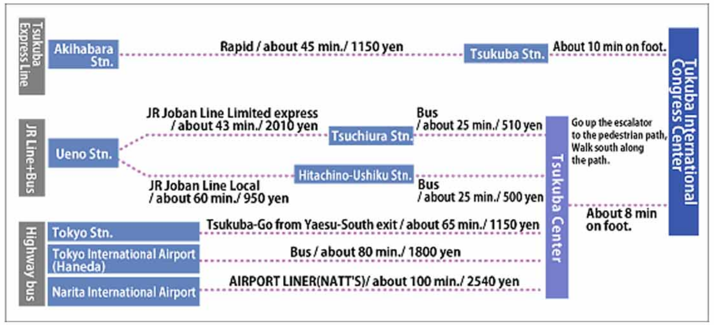
-Please e-mail all abstracts to the conference secretary.

E-mail: asa@swim.taiiku.tsukuba.ac.jp.

(Please refer to the guide line on the HP. http://swim.taiiku.tsukuba.ac.jp/asa/)

Access





ASA Secretariat

University of Tsukuba, Institute of health and Sport Sciences

1-1-1 Tennoudai, Tsukuba City, JAPAN

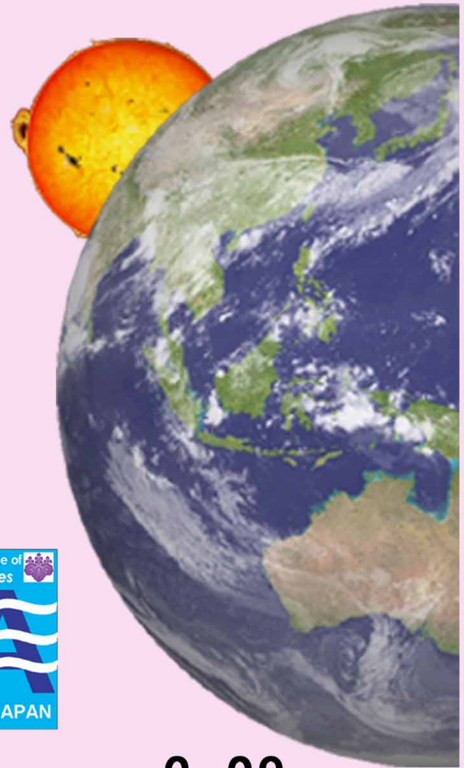
Tel and Fax: +81-29-853-6338

E-mail: asa@swim.taiiku.tsukuba.ac.jp

2008

1st International Conference of Aquatic Space Activities

Final Circular



1st International Scientific Conference of Aquatic Space Activities

ASA

2008 Tsukuba city, Ibaraki, JAPAN

2008.3.25 (Tue) ～ 3.28 (Fri)

Tsukuba International Congress Center

Organizer：ASA Organizing Committee

Corporated by：Tsukuba City University of Tsukba

Ministry of Education, Culture, Sports, Science and Technology

Japan Swimming Federation Japan Swimming Club Association

Tsukuba City Board of Education

Ibaraki Prefectural Board of Educaton

Tsukuba Convention Bureau Japan Sport Facilities Association

http://swim.taiiku.tsukuba.ac.jp/asa/

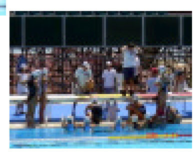
The Faculty of Sport Sciences, Univ. of Tsukuba will be proud to welcome colleagues from all over the world at the 1st Aquatic Space Activities International Scientific Conference of (ASA). The conference is held in Tsukuba, Scientific City of Japan and University City of the President of the International ASA-Conference, Prof. Dr. Takeo Nomura.

Purpose

The main purpose of the conference will be to exchange the research findings, to discuss ideas, concepts and to initiate new projects in the area of ASA. Conference activities will be: Invited lectures, oral presentations, poster sessions, meetings of the assembly, pool-side demonstrations.

The International Scientific Conference of Aquatic Space Activities (ASA) is for people working either scientifically and/or practically on topics as:

- Competitive – Recreational - Masters swimming
- Synchronised swimming
- Water polo
- Water-exercises
- Fin-swimming
- Triathlon
- Scuba-diving
- Any other water activities



Language

The official language is English - Japanese Language is allowed - when the abstract is written in English. All Publications will be in English. All papers will be reviewed before accepted for presentation and publication.

Contact

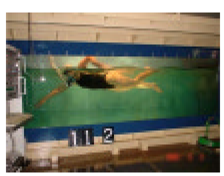
For more information –call for papers, travel to Japan, etc - please do not hesitate to contact

bodo.ungerechts@uni-bielefeld.de

(Chairman of the Organizing Committee) or

taka@swim.taiiku.tsukuba.ac.jp

(Secretary of the Organizing Committee)



Location

The conference will take place at EPOCHAL TSUKUBA International Congress Center in Tsukuba. The city of Tsukuba is directly connected to Tokyo International Airport (Narita) about 90 min by Airporter Bus. The city of Tokyo can be easily reached by direct train in about 45 min.

Accommodation

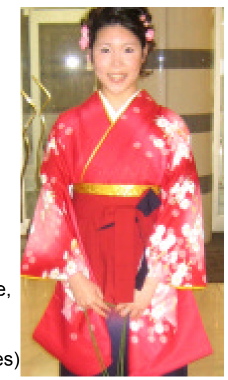
Hotels of international standard are located next to the Congress Center

- reasonable room rates
- 11 restaurants (western food)
- healthy Japanese food

Participant's fee includes:

- Scientific Program participation
- Scientific Conference material
- Reception and farewell diner;
- Conference services by friendly people
- Free access to a computer room

Lunch and dinner you make your own choice.



Accompanying person's fee includes:

- social program of the Scientific Conference,
- reception and farewell diner;
- sightseeing tour offers (at reasonable prices)

Traveling

- the Organizer will grasp at an opportunity and do the best to provide special flight offers for meeting attendees from other continents
- it is marvelous Cherry Blossom Season.

Conference Theme

Promoting the studies about Aquatic Space Activities

ASA - Conference is aiming at promoting the international research, the developments and innovations in the context of Aquatic Space Activities.

ASA-Conference is dedicated to the concentration of scientific based reasoning of the "WATER-Activities" ranging from Olympic Sports to physical activities related to performance and health aspects. Researchers, instructors and coaches will have the opportunity to discuss their views.

Invited Speakers

Competitive Swimming

Patric Pelayo (University of Lille / FRA)

Water Polo

Milivoj Dopsaj (Police Academy / SCG)

Triathlon

Huub Toussaint (Free University of Amsterdam / NED)

Fin-swimming

Laurent Baly (University of Mediterranee / FRA)

Water Exercise

Jan H. Prints (University of Hawaii / USA)

Scuba-Diving

Yoshihiro Mano (Tokyo Medical and Dental University / JPN)

Diving

Robin M. N. Hood (FINA Technical Diving Committee / NZL)

Topics

Presentation of the results of the study / a lecture mainly on the following topics will be included

Competitive swimming   Water Polo   Diving
Water Exercise   Triathlon   Synchronised Swimming
Fin-Swimming   Scuba-Diving   Master's Swimming

any other water activities.

Organizing Committee

Takeo Nomura (University of Tsukuba, JPN) - President
Bodo E. Ungerechts (University of Bielefeld, GER) - Chairman
Shozo Tsubakimoto (University of Tsukuba, JPN) - Chairman
Hideki Takagi (University of Tsukuba, JPN) - Secretary General

Nomura.T.(JPN)

Ungerechts BE.(GER)

Schedule

3.25 (Tue)

PM : Registration   Keynote lecture   Welcome Party

3.26 (Wed) – 3.27 (Thu)

AM : Invited Lecture   PM : Podium & Poster Presentaiton

3.28 (Fri)

Invited Lecture & Japanese Session (International Swimming Research Symposium*)

Farewell dinner

*** International Swimming Research Symposium (ISRS)**

The symposium about swimming research for domestic participants.
All presentations in ISRS will be presented in only Japanese.

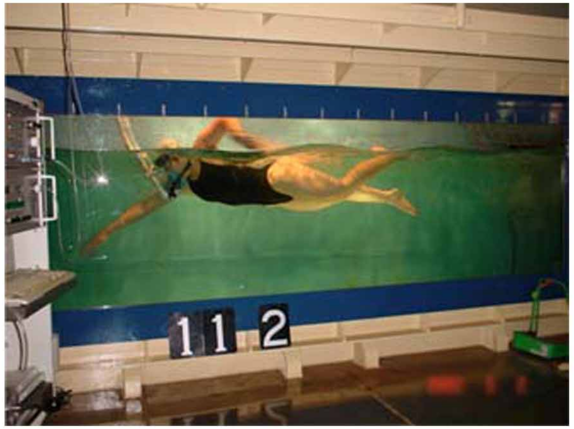
Programme

Keynote Lecture
Invited Lecture
Podium & Poster Presentation
Exhibition of a support company
Welcome Party
Farewell dinner
Excursion

Shrine of Mt. Tsukuba

Language

The official language is English. All publications will be in Engulish. Japanese language is allowed in the Japanese Session (8th ISRS).



The Book of Proceedings of the 1st International Scientific Conference of Aquatic Space Activities

TSUKUBA, JAPAN, March 25 to 28, 2008
Tsukuba International Congress Center

Conference Chair. **International Scientific Conference of Aquatic Space Activities Organizing Committee**

The Book of Proceedings of the 1st International Scientific Conference of Aquatic Space Activities

Editors: Takeo Nomura and Bodo E. Ungerechts
Publisher: University of Tsukuba

List of Contents

Invited Lecture

FINSWIMMING RESEARCH - PAST, PRESENT AND FUTURE

Baly Laurent[1], Gouvernet Guillaume[1], Barla Charlie[1]

[1] Decathlon Research and Development

4, Boulevard de Mons - BP 299

59665 Villeneuve d'Ascq Cedex - FRANCE

Introduction

Finswimming is as old as swimming. Techniques but also technologies have been changed since our ancestor until these last centuries. The last thirty years have seen the most important changes in the finswimming history for four reasons: teaching swimming has become an obligation at school, the democratization of holidays has generated an interest for aquatic activities like fin swimming, development of industries has created a new market on fins and finally the first competitions has accelerated the optimization of products and specifically the monofins. These changes have been studied and supported by different scientific areas such as biomechanics, hydrodynamics, physiology, and psychology. This review is divided into three sections, the past from 1970 to 1997, the present (last 10 years) and the future, and focused specifically on fins and their uses. The future addresses the work that should be attempted in the next ten years.

Past (1970-1997)

Although we can find some systems intended to help the swimmers from Assyrians (Fig; 1a) or L. de Vinci (Fig. 1b), fins had been invented by Captain Louis de Corlieu in 1933 for a military purpose. He submits to French army what he named swimming propeller (Fig. 1c), but in front of their refusal this practice carries on in civil world for leisure. The first competition took place in 1936 with for the first time measured velocity of about 1 m/s. But acknowledgement was really for universal exposition with fin swimmer moving in a human aquarium. Churchill was very

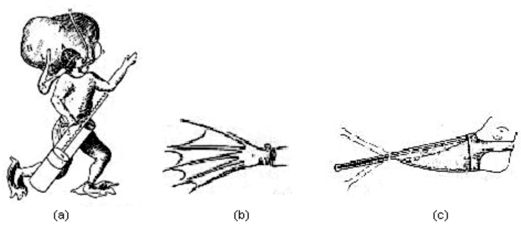


Fig 1: Plans of various evolution concept of fin, (a) Assyrians, (b) L. de Vinci, (c) L. Corlieu.

interested and Navy has created the first frogmen following by Canadian and Britannic armies. Fin swimming continue his expansion in leisure area. In spite of the most important researches had been made by army, it is important to notice that for one of unusual time army technology is descended to civil product.

Since the first works were used by military, all other researches had been realized to complete the equipment of naval frogmen. Military purpose was to go deeper and longer, they have focused their investigations on human body physiology to fight against cold and deep, urge on researches to focus on respiratory systems [Pendergast 1996], and fins for higher deep. Other military researches had been concentrated on fish motion observations (Fig 2) [Rosen 1959]. But more of this new product, like fin with spring or with rubber weaving, will have let to subjective judgements from inventors.

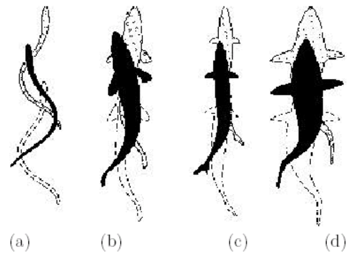


Fig. 2: locomotion pattern : anguiliform (a), subcarangiform (b), carangiform (c), et thunniform (d) (classification by Lindsey).

In 1970, animal’s motion had been an important innovation source in leisure world [Ungerechts 1983, Colman 1999]. Dolphin motion was worthy of attention for a particular motion and his difference between upper and down kick and fin shape which were adapted easily in fin swimming industry. Russia came in competition with new fins: a fibber glass monofin. In this way they had imitated transversal fish wave undulating from the head up to the trail. World records were pulverized, decreasing by 20 seconds on 400 meters. Two years after, only monofin exist in competition. With performance requirements in competition activities, researches have been focused on two areas: training effects and fish vortex generation.

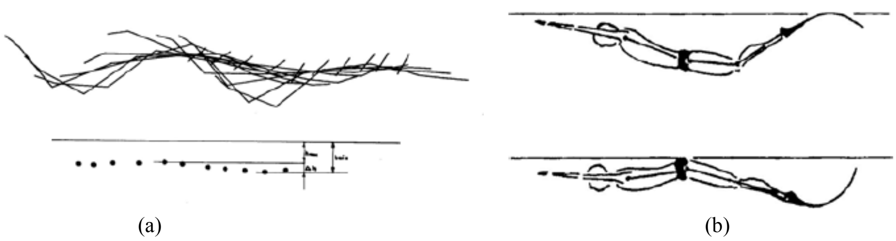


Fig. 3: fin swimming analyses by (a) Manoni (1985) and (b) Arellano (1985)

Motion analysis started off well to improve motion for a better efficiency. This second fin step development had been inspired by all swimming techniques studies (Fig. 3) [Counsilman 1968, Clarys 1983]. Training begins to study kinematics to improve finswimming techniques [Manoni 1985, Arellano 1984]. These works have proved that women swimming techniques is more efficient than men [Dutto et Cappaert 1994]. This difference is the consequence of muscular power lack. Indeed, it had been explored in order to optimize the different motion part on competition tasks (undulation, turn), by improving women muscular power, and by improvements on men swimming technique. Firstly, for a swimming activity, this research line has obviously been investigated with a correlation between anthropometrical data and swimming parameters such as frequency stoke (f), velocity (v), and cycle length (Lc). With this correlation, training has been adapted according to gender and morphology [Kennedy et al 1990, Rouard and Billat 1990]. In swimming Toussaint has proved determinant factors in drag intensity set up during children growth to keep always a linear velocity and active drag ratio. With improvements on techniques and records, finswimming became an absolute gliding sport, recognized in 1986 becoming an Olympics sport. [Ungerechts 1983] compared the swimming data from butterfly swimmers and dolphins; he has shown that vortex kinetic energy is a function of mass of water moved and the square of velocity displacement. So you can move a little mass of water quickly or move a greater mass more slowly for the same energetic cost [Counsilma 1971]. It's the explanation of better efficiency for a monofin use. Display techniques has carried on to progress since the first investigation permitted more observation and understanding of vortex generation [Lewis 1979]. Initial works were focused on kinematics analysis of the foot and the lower extremities to highlight their relations with injuries [Persyn 2000, Toussaint 1988].

Finally, all methods and researches in swimming have been transferred to finswimming. After all these biomechanical studies, hydrodynamics have helped swimmer to optimize his position and movement in order to decrease active and passive drag [Clarys 1978, Colwin, 1985]. In the early 90's sport have been democratized, helped with technological developments. News designs and materials more centred on practice allow initiation for novices. The better example is the appearance and development of first plastic fin. In 1993 a second revolution with a new concept of foot pocket had been realised with a plane structure. This democratisation was possible thanks to new brands creation and development which, permit to researches to found funds to expand their investigations.

Present (1997-2007)

During the last ten years, new methods and technologies have permitted a better observation and motion analysis. With new 3D recording system the determination of segment organisation and motion have been improved [Cappaert 1999]. Moreover, Sanders has determined the lower leg motion analysis for a water polo [Sanders 1999]. More studies had been dedicated to finswimming and not only crawl or butterfly. Democratisation of these data acquisition system in the 90's has permitted to leisure brands to lead competition researches to obtain better results.

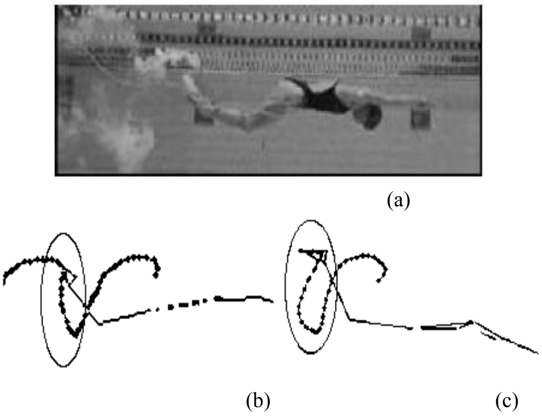


Fig. 4: Video capure for visualisation of (a) votex generation at the upper kick and motion of lower limb of a fin swimmer (b) Expert (c) Novice by Arellano 2002

The first kinematics studies, previously mention, have been completed with a measurement of drag, efficiency, or motion for different fin swimmer level. With video analysis Colman and Arellano have studied relation between motion and efficiency. In comparison with fish undulation which generates two vortexes at each kick, novice's fin swimmers are not able to generate vortex at the upper kick. However expert with an appropriate kinematics use joint ankle for generate this upper vortex which increases their efficiency and so on the velocity (Fig.4). Thus, generated vortex by undulation of swimmer, take shape of swirling system with high and low pressure zone to allow generation of propulsive forces. These studies have been generalised for fin swimming [Colman et al. 1999, 1997] and one of the explanation is that fin swimmer lean on this vortex to accelerate. In the same way, motions for different practices were studied, and differences were observed, as fin swimming on surface or in immersion [Baly 2002] or on a modelling objective [Baly 2002, Rejman 1999]. For example the same kinematics shape is observed when body is in a ventral position or in a dorsal one [Arellano 1999]. Stroke frequency and kick amplitude are the major parameters which change in regards to level of practice or distance race. In order to optimize his efficiency on long distance a fin swimmer reduces his velocity of 20% and increases his amplitude stroke. But amplitude increase is also due to the use of soft fin [Baly 2001]. However, with results obtain on participant at the European championship in 1983 and 1984, difference were uncover between the best team and other country. Best team have a knee angular flexion of nearly 133,5° whereas for other this flexion was only 102,5° [Arellano 1984, Gautier 2002].

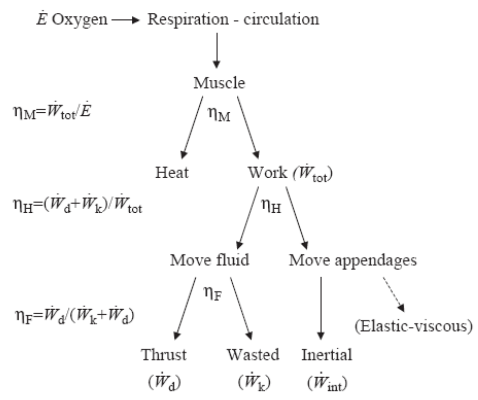


Fig. 5: Digraph of the energy conversion for the locomotion in the water by Zamparo 2005

Then, fin design and material have an influence upon kinematics. Moreover to use the best stiffness, a huge importance is attached to energetic aspect, in order to quantify efficiency of finswimming. Because monofin swimming is not easy to practice, Zamparo concentrated a part of these studies on diving fin. The use of fin reduces not only the stroke frequency but also energetic cost. Muscle energy is directly related to CO_2 consummation. A part is directly transform into heat, but the total useful energy (W_{tot}) is used to give motion to swimmer (W_{int}) and the last part to set fluid in motion. However, a part of this flow is wasted but a majority of it is used to cancel trust against forces (Fig.5). To make an energy statement, Zamparo uses works from drag wave and analogy to energetic cost for walk. To evaluate this last one with and without fin, Zamparo shows that fins reduce of 32% the wasted energy and therefore decrease of 36% the total energy expenditure, for the same velocity. All these methods are intended to optimise motion, but recently new production methods are born. So it is important to evaluate influences of different sizes and stiffness of fins [Zamparo 2005, Bideau 2002]. Another studies tend to tackle this subject by electromyography on fins swimmers. Muscular pattern are similar as crawl, indeed no difference are observed between different fin designs but significant correlation have been prove between fin surface and performance [Cabri et al. 1992]. Later with energetic method, Zamparo experiments more correlation and prove a direct effect of size and stiffness on energetic cost. Other approaches based on animal observation measure dolphin flipper size and stiffness [Walker 2000]. Bideau and al., 2002a measure the same parameters in a new method adapted to fin swimming. On the other hand, other studies propose methods to measure drag forces. These evaluation systems derive from swimming researches. There are two means to estimate drag forces, direct and indirect method. The first one directly measures forces produce by the arms, like MAD (measurement active drag), which consists to evaluate hand impact forces on underwater pads. Nevertheless, this method can't be applied on fin swimming and so indirect method is used, named VPM (Velocity perturbation method). It consists in pulling at a maximal speed a body shape whose drag forces are known. Results can fluctuate with morphological differences between subjects and their notion of supra maximal effort. It results in the creation of Active Drag Evaluation System by Bideau and Colbert. Swimmers pull a cable at their maximal velocity which is continually recorded, and strength resistance is controlled by torque output. This method allows to quantify thrust forces at each moment of motion cycles.

Thanks to improvements of production means, measurement technology has improved too. After a lot of years of empirical observation dedicated to measure fish undulation, leading techniques are used for finswimming. One of the first investigation uses visualisation by bubbles injection or by bubbles wall. After that, Particule Image Velocimetry (Fig. 6) allows to measure 3D velocity flow (Witte, 2006). Recently

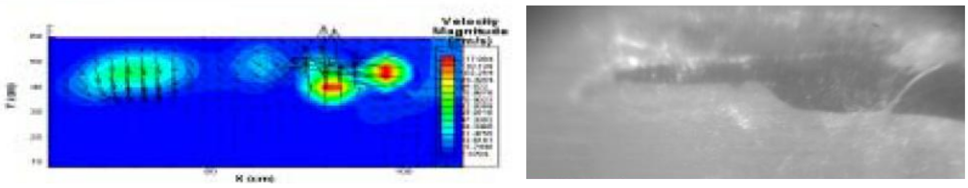


Fig. 6: DPIV Analyse (Digital Particule Image Velocimetry) McIntyre 2003

Hashizume (2005) develop solution for a new PIV measurement for monofin swimmer.

New means of observation and measure allow more specific measurements for numerical validation. During this last ten years, swimming modelling tend to develop on different viewpoints. Ones are centred on pressure of flow [Luersen 2004] whereas other focus. on biomechanical model to assess muscle forces [Nakashima 2007]. This last model estimate muscles strength for swimmer on his model (SWAM). For this thrust, forces fluids and buoyancy pressure have been modelling. This method is applicable for swimmer but for fin-swimmer it always exist fin deformation and so issues of flow and materials interaction. Interaction model are more complex to make in use for bigger deformation. Luersen, in 2004 (Fig. 7), creates a segmental fin model with five spring torque for fin modelling. With his computation, optimal torque distribution on fin was computed. This 2D model was one of the own model developed.

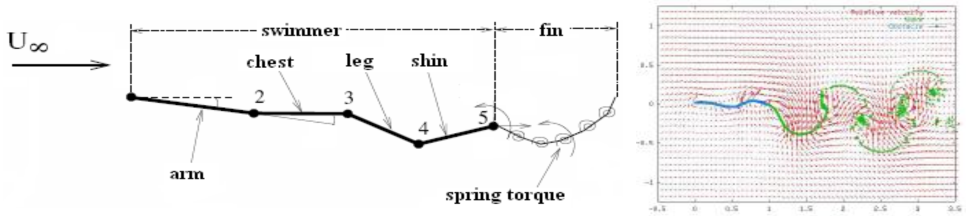


Fig. 7: Luseren's segment model with flow computation

It exists for other application models who can compute fluids-structure interaction using two description methods: a Lagrangian one for material and an Eulerian one for flow part. Risks with these 3D models are mesh, because methods to mesh flow or material part have to be well described to permit a good computation. Other issue is the materials parameter necessary for computation. In this way, investigation have to progress for a better description of mechanical parameter with the increasing of chemical formula number.

Biomechanical model for fin swimmer are now developed as for walking footwear activity [Buchanan 2005]. They are based on an inverse dynamic method coupled with muscular activation measurement in order to predict joint strength and moments during motion. This method begins to be used for swimming but requires many improvements and adaptations for fin swimmer.

Future (2005-2015)

Finswimming researches have made substantial progress in the last 40 years sustained by a promising market. However, one can suggest what should be done in the next few years. This fin market will probably diversify with new tendency for a democratized use. By the past, evolutions have always followed three research directions like kinematics to respond to use, modelling to understand phenomena and material to improve efficiency. New methodologies and the bright young researchers joining the field will provide additional substantial and exciting development and progress in the next ten years. Indeed, the next step will be to adapt finswimming to each people in order to increase their comfort and avoid injuries during their uses. That's why, measurements of mechanical parameters of fin components will be a great interest for research and innovation in finswimming, in order to practice for longer time without great effort or to increase performance by increasing velocity and flow. The second great line is modelling to predict effect of new design and material. The future objective will take place in optimisation of modelling and success of couples biomechanical models and hydrodynamic modelings.

REFERENCES

Arellano, R. (1984). "Criterios para la Evaluacion de la Tecnica en Natacion con Aletas." Natacion, Saltos y Waterpolo, 6(36), 20-31.

Arellano, R. (1999). "Vortices and Propulsion.", In R. Sanders & J. Linsten (Eds.), SWIMMING: Applied Proceedings of the XVII International Symposium on Biomechanics in Sports (1 ed., Vol. 1, pp. 53-66). Perth, Western Australia : School of Biomedical and Sports Science.

Arellano, R., Gavilan, A., and Garcia, F. (1999). "A comparison of the underwater undulatory swimming technique in two different bosy positions." Biomechanics and Medicine in Swimming VIII, K. L. Keskinen, P. V. Komi, and A. P. Hollander, eds., University of Jyväskylä, Finland, 25-28.

Baly, L., Chavet, P., Berton, E., and Favier, D. (2002). "Sex influence on kinematics parameters for elite finswimmers." Proc. of IXth World Symposium, Biomechanics and Medecine in Swimming, Saint-Etienne, 29.

Baly, L., Favier, D., and Durey, A. (2001). "Finswimming technical description by 3D kinematic study." Arch. Physiol. Biochem., 109(S1), 67.

Bideau, B., Colobert, B., Fusco, N., Multon, F., and Delamarche, P. (2002). "How to compute monofin's mechanical parameters ?" Proc. of IXth World Symposium on Biomechanics and Medicine in Swimming, Saint-Etienne, 32

Bideau, B., Colobert, B., Nicolas, G., Legueroue, F., and Multon, F. (2002). "Development of a new active drag evaluation system." Proc. of IXth World Symposium on Biomechanics and Medicine in Swimming, Saint-Etienne, 33.

Buchanan T.S., Lloyd D.G., Manal K., and Besier T.F., (2005) "Estimation of muscle forces and joint moments using a forward-inverse dynamics model.", Med Sci Sports Exerc. Nov;37(11):1911-6.

Cabri, J., Slagmuylders, V. and Clarys, J. P. (1992). "An ergonomic electromyography study on different swimming fins." Biomechanics and Medicine in Swimming IV, D. McLaren, T. Reilly, and A. Lees, eds, F.N.Spon, London, 105-110.

Cappaert, J. M. (1999). “Biomechanics of swimming analysed by three-dimentional techniques.” Biomechanics and Medicine in Swimming VIII, K. L. Keskinen, P. V. Komi, and A. P. Hollander, eds., University of Jyväskylä, Finland, 141-146.

Clarys, J. P., and Jiskoot, J. (1978). "Aspects de la résistance à l'avancement lors de différentes positions du corps chez le nageur." Sci. mot., 1, 71-82.

Clarys, J. P. (1983). "A review of EMG in swimming, explanation of facts and/or feedack information." Swimming Science IV, A. P. Hollander, P. A. Huying, and G. de Groot, eds., Human Kinetics, Champaign, 123-135.

Colman, V., Persyn, U., Zhu, J.P., and Ungerechts, B.E. (1997). “Movement analysis and computer animation in swimming and life saving.” Proc. Of Symposiumsbericht des Kölner Schwimmsporttage, Bockenem, 68-73.

Colman, V., Persyn, U., and Ungerechts, B. E. (1999). "A Mass of water added to the swimmer's mass to estimate the velocity in dolphin-lie swimming below the water surface." Biomechanics and Medecine in swimming VIII, K. L. Keskinen, P. V. Komi, and A. P. Hollander, eds., Gummerus Printing, Jyväskylä, 89-94.

Colman, V., Persyn, U., Zhu, J. P., and Ungerechts, B. E. (1999). "Movement analysis and computer animation in swimming and life saving.” Proc. Of Symopsiumsbericht des Kölner Schwimmsporttage, Bockenem, 68-73

Colwin, C. (1985). "Essential Fluid Dynamics of Swimming Propulsion. " A.S.C.A. Newsletter(July/August), 22-27.

Counsilman J. (1971) The application of Bernoulli’s principe to human propulsion in water. Lewillie L, Clarys J P (eds.), First International Synosium on Biomechanics and Medicine in Swimming, Brussels, 59-71

Counsilman, J. E. (1968). The science of swimming, Pelham Englewood Cliffs ed., London.

Dutto, D.J., and Cappaert, J.M. (1994). "Biomechanical and physiological differences between males and females during freestyle swimming." Med. Sci. Recre., 3, 16-27

Gautier, J., and Watier, B. (2002). "An analysis of kinematics parameters in finswimming." Arch. Physiol. Biochem., 110, 49.

Kennedy, P., Brown, P. L., Chengalur, S.N., and Nelson, R. C. (1990). "Analysis of male and female Olympic swimmer in the 100-meter events." Int.J. Sports Biomech., 6, 187-197.

Lewis E.R., and Lorch D. (1979). Swim Fin Design Utilizing Principles of Marine Animal Locomotion. Swimming III, p. 289-297 University Park Press, Baltimore.

Luersen, M.A., Le Riche, and R., Lemosse, D. (2004) Identification of a 3D Shape from a 2D Design: Application to a Swimming Monofin. In B. H. V. Topping, C. A. Mota Soares (eds.), Proceedings of the Fourth International Conference on Engineering Computational Technology, Stirling, United Kingdom (2004). Civil-Comp Press. paper 30.

Manoni, A. (1985). Aspetti di Biomeccanica nell'Analisi Sportiva (Nuoto Pinnato). Paper presented at the 1er Convegno Tecnico Internazionale di Nuoto Pinnato, Orta (Italia).

Hashizume, T., Matsuuchi, K., Nakazawa, Y., and Nomura, T., (2006) "Visualization of Flow Field behind a Monofin Using PIV" Nihon Kikai Gakkai Nenji Taikai Koen Ronbunshu, Vol. 6, 143-144.

Nakashima, M., Satou, K., and Miura, Y., (2007) “Development of swimming human simulation model considering rigid body dynamics and unsteady fluid force for whole body” Journal of Fluid Science and Technology, Vol.2, No.1, pp.56-67

Pendergast, D. R., Tedesco, M., Nawrocki, D. M., and Fisher, N. M. (1996). "Energetics of underwater swimming with SCUBA." Med. Sci. Sports Exerc., 28(5), 573-580.

Persyn, U., Colman, V., and Ungerechts, B. E. (2000). "Diagnosis and advice in the undulating strokes requires information on global body flexibility and upper limb strength." Applications of Biomechanical Study in Swimming, R. H. Sanders and Y. Hong, eds., The Chinese University Press, Hong Kong, 88-95.

Rejman, M. (1999). “Dynamic criteria for description of single fin technique.” Biomechanics and Medicine VIII, K. L. Keskinen, P. V. Komi, and A. P. Hollander, eds., university of Jyväskylä, Finland, 171-176.

Rosen, M. W. (1959). Water flow about a swimming fish . China Lake, CA: U.S. Naval Ordnance Test Station.

Rouard, A. H., and Billat, R. P. (1990). "Influences of sexe and level of performance on freestyle stroke: an electromyography and kinematic study.” Int. J. Sports Med., 11(2), 150-155.

Sanders, R. H. (1999). “Analysis of Eggbeater Kick Used to Maintain Height in Water Polo.” J. Appl. Biomech., 15, 284-291.

Toussaint, H. M., De Groot, G., Savelberg, H. H., Vervoorn, K., Hollander, A. P., and Van Ingen Schenau, G. J. (1988). "Active drag related to velocity in male and female swimmers." J. Biomech., 21(5), 435-438

Ungerechts, B. E. (1983). "A comparison of the movements of the rear parts of dolphin and butterfly swimmers." Biomechanics and Medicine in Swimming, A. P. Hollander, P. A. Huijing, and G. De Groot, eds., Human Kinetics, Champaign, 215-221.

Walker, J. A. (2000). “Does a rigid body limit maneuverability?” J. Exp. Biol., 203(22), 3391-3396.

Witte, K., Wunderlich, B., Betzler, N., Thévenin, D. Bordás R., and Edelmann-Nusser, J., (2006) "Examination of a Swimming Dummy’s Flow Field Using Laser Doppler Velocimetry.", 6th World Conference The Engineering of Sport.

Zamparo, P., Pendergast, D.R., Termin, A., and Minetti, A.E., (2005). “Economy and efficiency of swimming at the surface with fins of different size and stiffness.” Eur J Appl Physiol,96(4):459-70.

Diving

Robin M. N. Hood[1]

[1] Fina technical Diving

2008 JAPAN CONFERENCE – TSUKUBA UNIVERSITY, Ibaraki, Japan

INDEX

Beijing – 2008 Olympic Games athletic and aquatics stadiums

1. FINA

Diving is not considered to be a separate sport by its organising body, the Federation Internationale de Natacion (FINA). FINA governs four forms, or disciplines, of aquatic competition – swimming, diving, synchronised swimming and water polo.

Diving was popularised by the Swedes and the Germans in the 18^{th} and 19^{th} centuries. It grew out of the gymnastics principles developed in those nations. The first known book on diving was published in Germany in 1843. Competitive diving began in Britain in the 180's. In the late 19^{th} century a group of Swedish divers visited Great Britain and gave numerous exhibitions, which stimulated the formation of the first diving organisation, the Amateur Diving Association, in 1901.

Diving as an Olympic event was first contested at the 1904 Olympic Games in St. Louis, USA, and its appearance on the Olympic programme in both springboard and platform events has been continuous since 1908.

Two new events were added to the Olympic programme in 2000 the Sydney Olympic Games for both men and women, these being synchronised springboard diving and synchronised platform diving.

These events consist of two divers leaving the springboard or platform simultaneously and diving together as a mirror image of each other performing the same dive.

It has become a firm spectator favourite and is added another component to the highly telegenic sport that diving is.

2. AN EARLY PIONEER OF THE AQUATIC SPORTS PROMOTION.

Born in 1892, in Salt Lake City, USA, Lucile Anderson was a stenographer who was inspired by the pioneer swimming promoter, Annette Kellerman, to become a professional swimmer and diver.

Lucile Anderson's career was from 1912 through the 1940's. She was Kellerman's greatest imitator and competitor on the vaudeville, carnival and circus circuits.

Anderson was also the World Women's High Diving Queen who held the women's world record of diving head first from 102 feet into four and a half feet of water!

Lucile Anderson's and her compatriots historical legacy is not only the role played by female professional swimmers in promoting swimming and diving and female athleticism, but in creating the demand for swimming pools in every major city and small town in the USA, in the first half of the twentieth Century.

3. HISTORICAL USA DOMINANCE IN THE SPORT:

From 1920, US divers asserted their supremacy for several decades. Two great coaches can be credited for most of these early victories: Ernst Brandsten, an outstanding Swedish diver at the 1912 Olympic Games in Stockholm, and Fred Cady. Their ideas, teaching methods and contribution to the improvement of equipment enabled them to produce a constant stream of high-calibre American diving champions. Brandsten and Cady introduced a more flexible board with a moveable fulcrum allowing the divers to leap higher and perform move difficult moves. These "Brandsten Boards" were officially accepted and used until the late 1940s. The American school of diving combined the values of the German and Swedish heritage.

These pioneering USA coaches were followed by some of the great US coaching names during the 60's, 70's & 80's; Phil Moriaty, Hobie Billingsley, Dick Smith, Dick Kimble, Sammy Lee, Ron O'Brien. The list is extensive and many more names could be added. It were these men, and many women coaches also, that ensured USA remained dominant.

In fact, the United States has dominated the sport of diving, perhaps to an even greater extent than any sport at the Olympic Games. USA has won 47 of the 95 Olympic events from 1904 through 2004. This is a 50% tally.

USA has also recorded clean sweeps of all three medals in 17 of the 95 Olympic events since 1904, unmatched by any other country. Only SWE in 1908 in London and GER in 1912 at Stockholm had managed that feat.

Clean sweeps are now no longer possible because, commencing from the 1984 Los Angeles Games, the number of divers have been limited to two from each Country.

The gold medal statistics are:

1. USA 47
2. CHN 17
3. GER 7
4. RUS 7
5. SWE 4
6. ITA 3
7. AUS 1
8. CAN 1
9. DEN 1
10. MEX 1

However, there were some occasions when the might of the US was overcome and counties such as Italy, Germany and Russia defeated the best of the US.

Of recent years it has been China's turn to take the ascendancy and that is worthy of a story in itself.

4. BUT FIRST SOME OBSERVATIONS ABOUT THE SPORT OF DIVING

A: FEAR:

Springboard and in particular, Highboard (or Platform), diving includes an element that is generally absent in many other sports and one of the reasons why diving is relatively small in numbers.

That element is fear.

Not everybody likes the prospect of being 3 metres up in the air and throwing themselves off let alone being 10 metres high and doing the same thing.

At 10 metres (33 feet) the body is travelling at a speed of about 55kph (more than 30 mph) when the diver hits the water so there is a very real risk of injury.

So, 10 metre platform diving is a sport that is suited to a person with natural courage and enjoys the nervous excitement and natural adrenaline effects.

However, their coaches, many of whom were hurling themselves into a pool of water 33 feet below in their younger days, hope their tough divers never loose the fear. It is a paradox that the fear factor keeps the diver “safe”. If the athlete does not have a certain amount of anxiety that is when the possibility of serious injury is increased.

B: THE ADVANCE IN COACHING TECHNIQUES:

More than at any other time in the history of the sport modern coaching is incorporating in the athlete an awareness of the science behind their dives. The thought process of not just knowing how to do the dive but why certain actions on and off the board or platform produces certain physical effects. In short, understanding the physics of it all.

Part of this process is breaking down the parts of a dive into five, six or ten parts then putting them all together as the competition approaches. A word often used in this regard, both in diving and other sports, is “peaking”.

This methodology is not entirely new and has been used by many coaches over the years but what is driving the intensity of the method is the ever increasing competitive pressure of higher and higher degree of difficulty dives. Dives in the early 1990’s that were simply not seriously contemplated are now commonplace. Dives that were the preserve of the naturally stronger male athletes are now commonplace with female athletes. Cutting edge dives that the men were using in the 1964 Tokyo Olympic Games, and in some cases with difficulty, have now been perfected and exceeded by junior age group divers!

The list goes on and on includes the outstanding performances and shear courage and mental toughness of cliff divers and professional world high diving which is outside the scope of my paper today.

C: MENTAL STRENGTH:

All sporting codes have, as a key component to success, the mental toughness of the athlete. Without the desire to succeed, the desire to overcome, the desire to win, a fundamental foundation stone is not in place.

Coaches and experts may debate the foundation stones but they must all agree on at least five fundamentals:

1. Physical fitness
2. Mental strength
3. Physical aptitude for the sport itself
4. Outstanding coaching
5. The ability of the athlete to listen and obey.

Diving & gymnastics, also share another astonishing process. The coach visualises the finished dive. In other words the coach already has the video playing in his/her head. Then translates that mental video into spoken instructions which the diver translates into a physical action. This process is repeated and repeated and repeated with each repetition the action is stored layer upon layer in the mind of the diver and in the muscle memory so over a period of time the action is refined, buffed and polished into the finished product. At Olympic, World Championship level the women have five dives to perfect and the men seven.

---

5. EQUIPMENT EVOLUTION

Technical improvements in equipment, new dives with higher degrees of difficulty, scientifically founded methods of coaching and new attractive international events has helped diving develop to the current high standard.

Until 1920, high platforms were frequently temporary and shaky structures made of wooden scaffoldings. Then concrete towers with vertical stairs replaced the wooden constructions, and today many of them are equipped with elevators. The surface of the platform is now covered in a rubberised or synthetic material making the surface non-slip safe and of consistent texture the world over. In addition the lighting of modern indoor pools has made highboard diving safer also, particularly when the intensely more complicated dives are now being done regularly by both men and women.

The Beijing Olympic Games “water-cube” National Aquatic Centre is an example of the outstanding standard to which diving facilities have elevated to and the photograph of the diving pool is a graphic example.

National Aquatic Centre, Beijing, China. Venue of the 2008 Olympic Games

From the early days of the springboard and of the wooden planks covered in coconut matting, emerged the laminated wooden versions out of which the laminated Brandsten board in the USA generally being regarded as the best but this was was quickly replaced by an aluminium board used at the 1960 Olympic Games in Rome.

Then Ray Rude of USA developed the "Duraflex Board", made of a single piece of tapered and riveted aluminium with a torsion box spine running the length of the board on the underside.

Finally, in 1969, the "Maxiflex" double tapered board was introduced. This springboard is exceptionally strong and flexible allowing much greater height and lift to be achieved thus more dives with higher degrees of difficulty.

A dramatic example of the power afforded by the double tapered Maxiflex springboard is shown below. Note the depth of the flex as it is depressed and further, please note that the diver has achieved this from a standing position. You can imagine the further depth of flex when the diver uses the forward running approach with a hurdle step. In one metre events it is not uncommon for the tip the Maxiflex to break the surface of the water (or "Cheeseboard" as it is sometime called).

Montreal, Canada. Venue of the 2005 FINA World Championships

Please refer to Appendix A for a very interesting historical synopsis of the positive development of springboards that has revolutionised the sport and I acknowledge former Olympic Games champion 1956, Melbourne, **Bob Clotworthy, USA** for this very informed article and worthy of dissemination.

6. 2004 ATHENS OLYMPIC DRAMA:

AN UPSET RESULT BROUGHT ABOUT BY AN UNEXPECTED OUTSIDE INFLUENCE.

It was the Olympic mens' 3 metre springboard final. The eight best teams in the world contending for three medals with the Gold the ultimate with its attendant glory and plus, in the case of some nations, a not insignificant amount of monetary reward. It is my understanding that the Chinese synchcronised divers would collect USD85,000 if they won the gold this day!

The contest was tight. After four rounds of six the Chinese had edged ahead and it looked as though they would hold and increase their lead in the final two rounds despite the Germans, Americans, Australians and Russians hot on their tails. The Greek team were eighth in a field of eight but not within striking distance.

Then suddenly, and completely catching everybody unawares, including the concourse & seating marshals, out of the spectator stands, onto the concourse and up on the far side three metre springboard appeared there appeared a young man dressed in a tutu acting as a clown and this, in the middle of a critical Olympic final!

The Referee, the divers, the judges, all the officials and athletes were non-plussed, indeed stunned. Nothing like this has ever happened before. The competition was interrupted at a critical point. It was unable to proceed until the clown was removed from the board and the pool and this, was as it turned out, going to take some time.

One of the Greek senior officials endeavoured to reason with him but without success. Shortly after a solitary security guard joined the Greek official but the clown on the board refused to come down. Finally he dived off the board and continued his antics in the water. Eventually he made his way to the side of the pool and was escorted out of the field of play.

By this time the rhythm of the contest had been broken and when the event was able to continue it was obvious the divers' concentration had been compromised. One by one the main medal contenders' edge had disappeared and this was reflected in the marks. By the start of the sixth and final round, much to everyone's surprise Greece found itself in the leading bunch. They were the only ones who had not made a mistake in round five. Perhaps because, physiologically, they understood they were not serious medal contenders and had not been too much affected by the clown's nonsense.

So into the final round we went. Naturally it was expected that China would retain its slim lead. This view was strengthened when one by one the teams closet to challenging the China teams made serious mistakes.

One by one each, with the exception of the Greek team, made an error of some sort. Some of these mistakes were fatal. One diver of the USA team inexplicitly lost power in his hurdle step leg; it buckled and he while he was able to complete the dive it was so badly done that the low synchronisation and low execution marks slid the team down the list. One of the Russian team struck the board with his feet in an inward 2½ somersault. The judges' marks reflected this and the Russian team dropped down the list and out of contention.

This left the China team in an unassailable position with the Greek team still error free and in second place going into their last dive. At this stage the Greek team had completed their last synchronised dive and were in first position with the China team yet to do their last dive.

China had the gold in their grasp. All it required was for them to perform their synchronised reverse 3½ twisting 1½ somersault, even in mediocre fashion, for them to exit the pool and receive the ovation of the packed stadium.

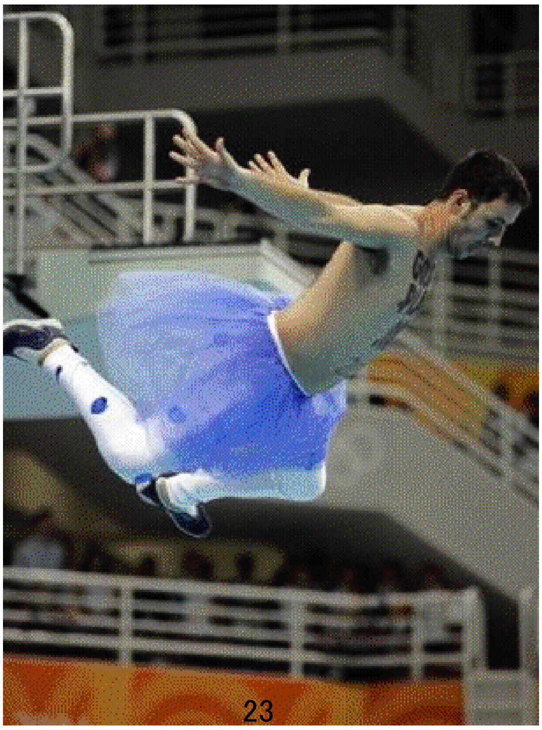
Then an unexpected drama unfolded. One of the China divers failed to complete his dive. He simply lost control in the twisting movement, the dive unravelled and he landed on his back. At the same time his team mate performed perfectly but his partner's error was fatal. The Referee failed the synchronised dive (because there had been no synchronisation) and the Chinese was awarded zero points! To rub salt into the wound not only did the China team not win the gold medal but they did win the substantial amount of money on offer by the Chinese authorities for their gold medal winners!!

This left the eighth seeded Greek team the outright winners with the silver and the bronze going to Germany and Australia respectively.

The stadium was filled to maximum capacity, the majority of whom must have been Greek citizens judging by the huge eruption of cheers that, had not the stadium been securely constructed, would have lifted its roof off! An incredible scene ensued with incredulous rejoicing in the spectator stands and on the pool deck. The totally unexpected circumstances

And all this triggered by the stupidity of the clown who disrupted the contest and the surprising lack of security on the pool deck that allowed this idiot to so easily gain access to the field of play and play out his crazy publicity plan! Such are the moments of Olympic drama.

Ironically the clown has earned his place in dishonourable history because we continue to speak of it to this day. Fortunately I have no wish to know his name.



7. THE EMERGENCE OF CHINA DOMINANCE

At the thousands of sports schools in China there are more than 6 million young athletes. It is part of an increasingly aggressive sports programme the Chinese hope to showcase in 2008 beginning with the opening ceremony on 08.08.08 (eight being an auspicious number in China and series of eights particularly so).

For a nation that has for generations largely avoided involvement with the West, the 2008 Olympic Games represent a chance for China clearly seeks to seriously grasp the opportunity to make a stunning impact as a modern athletic and economic power.

In the publication USA Today there are some interesting observations:

1. At least 70% of China’s full-time athletes graduated from specialised state schools. State schools still provide the basis of sport in China.

2. The Chinese sent its first Olympian to the 1932 Summer Games, but China does not have a long history of Olympic achievement.

3. China’s claimed its first Olympic gold medal at the 1984 Los Angeles Games when shooter Xiaoxuan won the 50m rifle event. That summer china won 15 gold medals and 32 overall (fourth overall behind USA, Romania and West Germany in a year when the Soviet Union boycotted the Olympics).

4. Four years later China’s gold medal total dipped to five (interestingly of which diving accounted for 2 – women’s, 3m and women’s, 10m).

5. China does not make public what it spends on sports programmes, but Steve Roush, the US Olympic Committee chief of sport performance, estimates China is spending USD400,000,000 to USD500,000,000 to train elite athletes in the four years leading up to the 2008 Olympic Games. That does not include younger athletes training in sports schools. By comparison the US Olympic Committee and the sports national governing bodies will spend UDD200,000,000 to USD225,000,000 during that period.

My TDC colleague, Tom Gompf, recently observed that China's dominance in diving the answer is not complex (and not necessarily in this order):

(a) As already observed, endless support from the sports department and individual sponsors in terms of financial support. For the elite athletes at least, all costs of facility expenses and training equipment are paid fro by the local or central sports departments.

(b) Great financial incentives/rewards to the successful athletes from the Government and private business owners. For example, USD100,000 Awarded to the 2004 Olympic gold medallist as well as to the coach!

(c) Superior and advanced training facilities, particularly in dry land area and equipment. Almost all diving teams in China have an international standard indoor diving pool and their dry land facility will have at least 6 dry boards and 4 trampolines. Their National Training Centre has 18 dry boards and 10 trampolines.

(d) Body type and talent selection are conducted at an early age. Most young divers are chosen from gymnastic schools at the age of 6, to start diving.

    In this regard please note an example, one of literally thousands of athletes; the former discus thrower, Zhang Jinmei, says she fell out of a kayak as a teenage when a coach took her out for a trial run. She says "I had never rowed a boat before; I did not know what a kayak looked like and I couldn't even swim". She says she was picked for kayaking because she was tall and stout with good upper body strength. She won the 2004 World Cup in her event.

(e) Military type organisation and administration is the system of Chinese sports. They are in total control of the athletes including specific daily training hours, room and board. Athletes and coaches live in the same place. Almost 24 hours of supervision are watched by the coaches and team administrators.

(f) The line system from regional to provincial to national builds up to one overall support system , The National Training Centre, and one common goal: to win gold in all international competitions.

(g) Advanced raining techniques shared and taught amongst the coaches and from there inculcated into the divers.

(h) Tremendous volumes of training as already mentioned. It almost seems that academic study is secondary in their lives.

(i) An incredible amount of personal sacrifice and dedication form all levels – coaches, athletes, administrators and (also very important) from parents – divers get to visit their parents for about one week, once a year! It seems normal for coaches and their husbands/wives to be separated for several months at a time.

In the 2004 Athens Olympic Games China won 6 gold medals out of the 8 available. In the 2007 FINA World Championships in Melbourne, Australia they won 9 gold medals out of the 10 available.

According to Mrs. Zhou Jihong, Chair of Chinese diving, and a colleague of mine on the FINA Technical Diving Committee, "The most important factor is the strong support from the Government". Furthermore she goes on to say "Our "Dream Team" is not a castle in the air and only perseverance will prevail" a notion somehow vague until you are informed that Guo Jingjing for example, the current womens' Olympic and World Champion, does more than 50,000 dives every year to achieve the consistency of performance that wins gold medals.

Younger divers practice even more. "There is 10 years of hard work behind a one minute performance" says Zhou Jihong. But wait; there's more! - in training, every diver executes about 30 dives an hour eight hours a day six and a half days a week (this includes dry board and trampoline movements as well). That is 81,360 dives a year assuming no free days. Assume 21 free days a year (and there is no indication that there is that much time off); that's still 76,320 dives a year.

That is still a serious number! Even if you find these numbers incredulous the fact of the matter is that China and their system produce the results that other countries find difficult to emulate.

Lest it should appear all be doom and gloom let me tell you that the Chinese divers feel a great deal of pressure during the events; particularly in finals, and from time to time are beaten when everyone expects a China walkover.

For example, Laura Wilkinson, USA, has been the only female diver to win the Womens' 10m platform event at the Olympics, the FINA World Championships and the FINA World Cup. No Chinese woman diver has achieved this yet. Alexander Despartie, CAN, won the 2005 FINA World Championship Mens 10m platform event in Montreal. Gleb Galerin, RUS, beat the Chinese for the 2007 FINA World Championship. Dimitri Sautin, RUS, has beaten the Chinese in times past and, may it be said, the Greek synchronised diving team in the 2004 Athens Olympic Games and took the gold medal to boot!! And that’s another storey.

And, interestingly enough, at the recently concluded 2008 FINA Diving World Cup in the new Olympic “water cube” aquatic stadium late last month, the German Sascha Klein defeated the top seeded Chinese Zhou Lu Xin by 23.45 points to claim the Mens’ 10m Platform World Cup title. Third place went to the USA diver David Boudia ahead of the second Chinese diver LIN Yue by 45.80 points who came in fourth.

It was the only gold medal that China did not win out of the eight available but it does demonstrate the rest of the diving world is not “psyched out” by China’s dominance and continues to take the battle to them. The overall winner is of course the sport and the standard is remarkably high and ascending in difficulty and execution!

Let me leave you with this thought also: In a number of countries, New Zealand is certainly one, the political correctness brigade has for a number of years now, been “managing risk” and removing perceived “danger” from the public arena. One result is that diving boards have been taken out of some of the local swimming pools. Add to this the propensity in North America, particularly USA, to have the insurance industry and lawyers dictate what the sport can do to avoid risk and much of the feeder programmes are being lost due to the liability imposed on facilities and coaches. Actions like these damages sport development in as much as all sporting codes need to attract talented children to the sport and with out springboards or highboards in local communities to attract those children who gravitate to such, the supply chain starts to dry up. There is a great deal of truth in the adage “Build it and they will come”.

---

8. THE SALT LAKE CITY INCIDENCE AND FINA DIVING JUDGE EDUCATION

FINA have been very proactive to make sure that the two subjective sports within the aquatic family, diving and synchronised swimming, undertake and maintain intensive judge & technical officials training.

This is undertaken is by way of a series of FINA schools in various parts of the world. The School concept was preceded by a Clinic model where the clinician was one person whereas the School method has two lecturers.

You may all be familiar with the Salt Lake City 2002 Winter Olympic ice dancing judging problem where the clear winner in most people’s eyes including the viewing public was the Canadian team but the gold medal went to the Russian Team.

In the aftermath of the, allegations were made that the French judge Marie Reine Le Gougne was forced to vote for the Russians by her nations skating union. Her vote was allegedlly part of a deal trading a vote in favour of the French Ice Dancing Team

Marie Reine Le Gougne was later suspended because of misconduct!

This was an embarrassment to the winter Olympics and to the International Olympic Committee and the pressure that subsequently came upon IOC was such that, later, a second gold medal was awarded to the Canadian’s who had originally been awarded the silver medal!

One of the outcomes was that the IOC made a serious suggestion that all subjective sports should be taken out of the Olympic programme. By Subjective sports I mean those sports that rely upon the opinion of judges to determine the winners. This contrasts with the Objective sports where the winners are determined by those who codes are measurable in nature – the fastest time swum or run, the heaviest weight lifted, the highest bar jumped, etc.

Diving, is of course, a subjective sport and for many years (at least 50) we have built into the judging protocols various safeguards to avoid abuse of the system. For example,

in a 7 judge contest the highest and lowest judges marks are removed, the remaining three added together , multiplied by the degree of difficulty then divided by three fifths (so as to compare the results of a 7 judge contest with that of a five judge contest.
Furthermore in all Olympic Games semi-finals and finals, FINA World Championship semi-finals and finals and FINA Diving World Cup semi-finals and finals, neutral judging panels are used: that is to say the judges are from those countries that do not have a diver in the event.
Since the Salt Lake City debacle our rules were further strengthened by deleting the TWO highest and the TWO lowest judge's marks leaving only the three middle marks to be added, the total then multiplied by the degree of difficulty for the final score.
As already observed, the FINA funded and promoted judge education Schools further strengthen our integrity as a sport and this programme has been ongoing for about ten years, well before the Salt Lake City incident. In 2008 alone there has been and will be seven schools spread as far south as New Zealand and as far north as Holland. Last year Japan hosted a FINA School in Tokyo, one of another seven.
Naturally, FINA was able to demonstrate to IOC, and IOC accepted, that diving has a robust, transparent and defensible system of judging that ensures the correct consensual result of any event conducted under auspices of FINA; and including the Olympic Games.

APPENDIX A

Evolution of Equipment

"So far there has been mostly discussion about diving boards and some about fulcrums. Frankly, I think it is just as important to consider the evolution of fulcrums and standards because if you put a Maxiflex on a fixed fulcrum on a lousy standard there is no way that you are going to get optimum performance from the board.
Also, I think it important to consider the various venues used for the early Olympics and other diving events around the world. Nobody has yet mentioned what it was like diving in the early days, both in terms of equipment – weather included – at the different venues. So it appears to me that I am going to present you with a rather lengthy paper about the above-mentioned items. I will also be sending you some photos.

I have to admit there will be a touch of "travelogue" to this paper because I experienced so much in my own diving odyssey. This effort will, perhaps, provide some educational benefit, but I hope that it may also have some entertainment value. I'd like for the modern diver to have an idea of what it was like diving in my day – and before my time. After all, those who currently dive compete in heated diving pools with the same equipment from one venue to the next all over the world. And these venues all have hot tubs to lounge in between dives! Our diving travels were always an adventure – usually into an unknown and unfamiliar environment.

As you know, I am working on the history of diving so let's go way back. There is a wall painting of a diver that was found in an Etruscan tomb from the sixth century before the birth of Christ and a classical Greek fresco painting of a diver from about 480 B.C. But that's too far back. Move forward in time to 1776 when the first swimming club of Sweden was founded in the town of Uppsula. The club required its members to pass a test in swimming and diving. Continuing ahead – I have a copy of a drawing from 1844-1845 of the Lindska swim school in Stockholm in which there is pictured a steep diving board called a "vippen" that is angled about 40 degrees from horizontal. But again, this is simply history and doesn't really add to a modern discussion – so –

Diving boards – at least vippens – were probably developed sometime in the 18th century. Certainly the boards were made of wood and the most popular walking surface for many years was cocoa matting. We know that cocoa matting was used as early as the 1904 Olympics. However, some boards in the early years had no non-skid surface - none! Others had canvas, or rubber, or another artificially created surface, or a sand-like grit glued to the top of the board. Norman Buck and Ray Rude baked their non-skid surface on to the board.

DIVING BOARDS.

Wood. We don't know who actually built the original wooden boards, but Sweden, England and Germany were the diving powers in the 18th and early 19th centuries. Ernst (Ernie) Brandsten, who competed for Sweden in the 1912 Olympics, immigrated to the USA after the Games and for many years was the diving coach at Stanford University. He designed his own diving board that was built by the Van Arsdale-Harris Lumber Company of San Francisco. The original board was a single piece of white Oregon pine.

Later he manufactured a laminated board with as many as 12-16 pieces of wood glued together. In the 1920s, Brandsten, along with Fred Cady, the coach at the University of Southern California, calculated that the dimensions of a diving board should be 16 feet in length and 20 inches in width – dimensions that are the same today. The Brandston board was used in the Olympics as late as 1952.

In the 1940s and early 1950s the most popular wooden board was the Ray Daughters board that was manufactured by S.R. Smith of Portland Oregon. His board was the board of choice at the 1948 Olympics in London. Diving great, Earl Clark, came out with an excellent laminated wooden board that was concave from the fulcrum to the rear attachment. Lyle Draves said it had great action, but Earl had trouble with the glue and the laminations separated after a time. In the '40s and '50s, Kiefer, American, Paddock – many swimming pool equipment companies – manufactured wooden boards, some good, some bad, but the Brandsten and Daughters boards stood the test of time until they were made obsolete by the aluminium boards manufactured by Norman Buck (the Buckboard) and Ray Rude (the Duraflex).

In 1949, Vicki Draves, double Olympic Champion in London, travelled to the Philippines with her husband Lyle. Since her father was Filipino, Vicki was an idol there and for her exhibitions they had built her an 18-foot board out of Philippine mahogany. She said it was light and flexible, just right for her weight, and the best wooden board she had ever used.

Even though wooden boards were used for more than one hundred years, they did have a couple of problems. They sometimes warped, tossing a diver to the side, but more frequently they just became waterlogged. They became heavy and weak - then they began to sag. Drying them out was an option but that took a long time. Olympic and Hall of Fame coach, Phil Moriarty, told me he used to turn water-logged boards over so they no longer sagged downward. Eventually they did so he flipped them once again.

Fibreglass. In the 1950s several companies produced a number of boards that were called fibreglass. Make Naigles of Elmsford, New York built the Dolphin fibreglass board that was used in several national championships. In fact, the board was wood covered in sheets of fibreglass with a sandpaper type grit adhered as a non-skid surface. The board was heavy but good and durable because it kept water from penetrating to the wood and getting it waterlogged.

Paddock produced a fibreglass board that was used in the 1956 Olympics, but I don't know what was on the inside. In England, Wally Orner produced a double taper fibreglass board as did Hugo Speelmans of Belgium, but I don't know the exact composition of those boards. I dived on the Speelmans board in 1958 - it was quite light and had good whip. Norman Buck's son produced the "Starflight" board, but it had some problems and came along too late because the Duraflex had already started to corner the market.

Aluminium and Steel:

Ray Rude's Duraflex board was developed in the 1950s and the first time I dived on one was in the early part of the decade. At that time the board had three problems: 1. tremendous torque on the tip so that if you landed in the corner of the board you were thrust to the side, 2. Non-skid bathtub strips that were placed crosswise for the length of the board, but there was no non-skid material between the strips so there was the potential for slipping and 3. There was a curved lip that rose about a half-inch on the forward tip of the board, the idea being to provide a grip for back takeoffs. However, it was not comfortable for forward takeoffs and it was discarded. The divers told Ray of these problems and they were eliminated in successive models.

John Deininger has written about his experience with early Duraflex models and Mike Finneran wrote about Jack Roth and his reluctance to install the board and then his complete acceptance of the board. Gary Tobian, Olympic springboard champion in Rome – 1960, also provided Ray with considerable help in its development, particularly in the perfection of the non-skid surface.

As the diving world knows, the Duraflex was first used at the Rome Olympics and its improved versions, along with the standards and fulcrums, have been used in every Olympics since. However, before the Duraflex there were other metal boards. The Germans created a steel board in the late 1920s and brought it to the 1932 Olympics, but it was rejected for the competition. Al Patnik, many time national champion, told me that he had dived on the board in Germany in 1937, but said that it had no flexion - that it was very stiff. In the USA a Thompson aluminum board was produced in the 50s but diving from it was like diving from a slab of cement.

Jimmy Patterson of Ohio State, developed the Lifetime Aluminum board that was very popular in the Big-Ten Athletic Conference in the 1950s. The board was light and had a good snap to it, and although I used it in the 1956 Olympic Trials it was not selected by Australian officials as one of the boards used in the Olympic competition in Melbourne. The Patterson board was used in several national championships, but as with every other board of the era, it was surpassed by the Duraflex that cornered the diving board market from 1960 to this day.

Norman Buck acquired a large amount of surplus aluminum from World War II and had been making aluminum ladders. In 1948 he read that Ray Daughters was sending wooden boards to London for the 1948 Olympics so he decided to go into the diving board business. He produced a board that had telescoping tubes on the outside, I-beams in-between, and the whole thing was bolted together. After a number of trips to Ohio State for assessment, he worked out the kinks and he had developed a board that was used in a number of national championships. This was a board that could be repaired if something broke, certainly a great selling point. And - he had developed and manufactured the first light, flexible, durable, and practical non-wooden diving board, a board that was used in the 1952 and 1956 Olympic Games.

In my opinion **- Norman Buck deserves to be inducted into the International Swimming Hall of Fame as a Pioneer Contributor!**

Note: All of the fiberglass and aluminum boards had a manufactured non-skid surface. As a result, it was soon after the Helsinki Olympics that cocoa matting became obsolete for international competition. Also, it might be interesting to the reader that during the wooden board era, it was required that the forward tip of the springboard must be elevated above the rear attachment – as much as four inches! This was probably because a wooden board eventually sagged. When it was realized that the aluminum and fiberglass boards weren't going to sag, the rule was changed so the board had to be level.

Fulcrums:

Along with the Maxiflex diving board Ray Rude designed and manufactured Durafirm fulcrums and standards – again the elite of diving equipment. However, long before

Ray Rude arrived to the world of diving, a fulcrum and standard as well as the board were a necessary part of a successful diving facility. Ernie Brandsten developed the adjustable fulcrum and it appears from photos that his fulcrum was used at the Los Angeles Games of 1932. Photos from previous Games are inconclusive.

Prior to and even into the 1950s several types of fulcrums were used, most frequently a bar fulcrum, a wooden or metal bar with rubber on the top that came in contact with the board. Most of the time these were fixed fulcrums and the divers had no choice of fulcrum placement. However, Aileen Riggin, the women's Olympic springboard champion at Antwerp in 1920, told me that the male divers always took tools to the site of a national diving championship and they would adjust the fixed fulcrum in a spot to their liking.

Occasionally, we would run into a strap-fulcrum – a metal strap that went across the top of the board, holding it tight so that the board would not lift up when a diver bounced. The diver would have to step over the strap on the forward approach. Sometimes a board would have a double bar-fulcrum, two bars, one in front of the other, about 16 inches apart. This was, perhaps, an effort to preserve the board.

In the Mid-Ocean meet in Bermuda, the divers adjusted the "fixed" fulcrum before each dive. The fulcrum was a log, flat on the bottom and rounded on the top. To change the fulcrum one diver lifted the board and another moved the log.

Venues:

Modern divers experienced more consistency in the venues in which they compete. Sometimes they are indoors, other times outdoors, but the boards, fulcrums, standards, along with the separate diving pools are quite similar from one place to another. This has not always been the case. For example, in the early years the venues and conditions from one Olympics to another were vastly different. The Olympic sites for the earlier Games through 1960, along with the conditions at the time, are listed below.

Paris – 1900. There was no Olympic competition at Paris, but diving was on trial. Exhibitions were given from platforms into the River Seine.

St. Louis – 1904. The diving was held at the United States Life Saving Exhibition Lake, an artificial lake built for the St. Louis Worlds Fair. A platform was built on a dock in the middle of the lake and a springboard about eight feet long was fastened to the platform. The height was about three-meters. The fulcrum was fixed.

Athens – 1906. This was an unofficial Games according to the International Olympic Committee, but there were a lot of athletes present from all over the world. The diving was held from platforms at three levels – four, eight and twelve-meters – the platforms being attached to a tugboat anchored in the frequently wavy Bay of Phaleron.

London – 1908. Springboard and platform diving events for men only were held in a 100-meter pool. The diving platform was somehow lowered into the water when there was no practice or competition.

Stockholm – 1912. The diving was held in a swimming and diving course established in the Bay of Djurgardsbrunnsviken. It was protected on two sides by land, a third by a steamboat pier, and the fourth side by a line of floating pontoons. The water was cold. This was the site of the first women's Olympic diving competition – plain diving from the platform.

1916. The Olympics were cancelled because of World War I.

Antwerp – 1920. The competition was held in a moat that surrounded the city. It frequently rained and the water temperature was in the 50s. The water polo games were shortened because the players were suffering from hypothermia. For the first time a springboard event for women became part of the Olympic program.

Paris – 1924. The Olympic competition was finally held in a 50-meter pool but the diving and swimming events were held in the same pool, making it difficult from a practice standpoint.

Amsterdam – 1928. Once again a 50-meter pool was the site of the competition, but the concept of separate pools for swimming and diving would have to wait for the Berlin Olympics in 1936.

Los Angeles – 1932. Swimming and diving were again held in the same pool. However, a Brandsten adjustable fulcrum was available for the springboard divers - an Olympic first. Fortunately, Los Angeles is hot in the summer.

Berlin – 1936. For the first time, there were separate swimming and diving pools and spectator space for more than 20,000 people. This Olympic venue was the best ever. Unfortunately, it rained almost every day, and since the competition was held outdoors and fairly far north, it was cold for the divers.

1940 and 1944. No Olympics were held because of World War II.

London – 1948. For the first time the Olympic swimming and diving events were held indoors. Again, there was a single pool for both disciplines.

Helsinki – 1952. Two springboards were available for the divers, a Brandsten wooden board that was used by <u>exactly</u> <u>one</u> <u>diver</u> and an aluminium Buckboard used by all the others. Unfortunately the European divers had never dived on a Buckboard with a non-skid surface so cocoa matting was attached to the board. Naturally this changed the springing characteristics of the board but since the Americans were so used to changing conditions, the springboard divers won five of the six medals. Because Helsinki was so far north, it was cold, but hot tubs and saunas in the locker rooms helped.

Melbourne – 1956. This was the first Olympics that **did not** use a wooden board. The available boards were a Paddock fibreglass and an aluminium Buckboard. Again the Americans won five of the six springboard medals.

Rome – 1960. **The Duraflex Era began!**

Venues - Non-Olympic.

When I was a teenager in New Jersey I frequently competed in lakes, occasionally in a thunderstorm. Safety rules were not up to the current standards.

Low Ceilings and **Shallow Water.** These problems were frequently encountered in the early days. Low ceilings were usually found in old YMCA, club, high school or college pools. In one pool with a low ceiling, a padded beam was over the end of the diving board. When taking a practice bounce it was necessary to tilt your head forward as your shoulders hit the padded beam. In another pool I would push off the ceiling with my hand while doing a one-half twist.

All of the old timers dived into shallow water. I competed in a three-meter national championship into 10-feet of water, but frequently practiced in 8-feet of water. Other divers from the 1930s dived from 10-meters into less than 8-feet of water. I'm sure that Sammy Lee and others from the 30s and 40s have similar stories. We're not complaining – that's just the way it was.

For many years the Far Western Diving Championships were held at Fleischaker Pool in San Francisco. This was an oceanside pool, 1000 feet long with a T in the middle that had lifeguards in rowboats. The cold water was piped in from the ocean and rarely, if ever, made it to a temperature of 70 degrees Fahrenheit. The water was dark and the bottom slimy. According to Vicki Draves the 10-meter platform had a ladder going straight up – no angle and no safety concerns. The wind was so strong coming off the ocean that a glass panel was placed on the ocean side for protection. However, the wind was occasionally so strong that it moved the divers sideways. I was told that during one contest a flying pelican followed the divers in their plunge to the water.

In 1955 I competed in the Keo Nakama meet at the War Memorial Pool in Honolulu. This was a pool built into the Pacific Ocean at Waikiki Beach after World War I. The pool was 100-meters long and was fed by a series of openings that allowed the entrance of fish at high tide. At low tide the entrance and exit were closed so whatever fish were inside were stuck there until the tide changed again. During one platform workout we noticed that a barracuda was trailing a swimmer as he swam back and forth. We decided to sun-bathe until high tide. The other obvious problem was that the height for our springboard and platform contests varied with the tide. As I remember, we competed in the four-meter springboard and twelve meter-platform.

In the 1950s a number of American athletes traveled to foreign countries under the auspices of the United States State Department on what were termed "Good Will Tours. A number of track and field athletes were involved, as were Sammy Lee and I. I took three tours, in 1957 to Tunisia and another in 1957 to Chile and Peru. In 1958 my wife, Cynthia and I, took a trip around the world, conducting clinics and exhibitions in several countries of Asia, Europe and North Africa. Although conditions were not always perfect in the USA, the venues encountered on these trips were frequently far, far from perfect. It was not unusual for the host city or country to construct a board just for our performance. Below find additional samples of conditions I encountered in my travels.

After the Olympics at Melbourne in 1956, I toured Australia, giving exhibitions. Most of the conditions were good, but in Perth I gave an exhibition from platform at night with poor lighting into the Swan River. On my first practice dive (always feet first) I sank into river-bottom mud up to my knees.

From Perth I was flown into Kalgoorlie, a gold mining town in the desert of Western Australia. As the plane approached this town of 345 people, I observed from the air that there was a fifty-meter Olympic pool with five and ten-meter platforms. However, when I got to the facility I found there was a bank of lights about seven feet high right over the takeoff edge of the ten-meter. Obviously, my program was somewhat limited.

Olympic diver, Frank Kurtz, who was third in the platform at the Los Angeles Games in 1932, toured Australia before World War II and in Cairns they built him a wonderful wooden board, which they gave him after his performances. He took it with him on tour, then all the way to London.

In 1957 I toured Chile with Gunter Mund, who placed 7th in the springboard at Melbourne. His mother and father, who were both Olympic divers for Germany in 1928, ran a series of swimming pools in Santiago. They had a Jimmy Patterson Lifetime aluminum board that Gunter and I detached and installed at various pools around the country where we gave exhibitions.

However, this was not possible in every location. At the nitrite-mining centre in Pedro de Valdivia, inland in northern Chile, they had constructed a special diving board for Gunter and me. It was 18 feet long and heavy - and it cracked the first time I took a warm-up bounce. We, and the board, survived the exhibition.

In Iquique, a coastal city in northern Chile, they built us a platform about 8 feet high with an 8-foot run into 5 feet of water. Needless to say this was not our greatest diving performance. We did a bunch of feet first entry dives for ten minutes, then did a half hour of clown swimming and diving. However, the next morning the Iquique newspaper reported that we were the greatest entertainment to hit town since the Harlem Globetrotters!

On our world tour in 1958 I ran into mostly home-made boards that were OK – in other words, they were diveable. However, the most unusual board I encountered was in Taiping, in the jungles of northern Malaya (now Malaysia). I dived into a spring-fed pool on a homemade board that was T shaped. It was about 12 inches wide lengthwise with a T–shaped landing area about 18 by 20 inches. I must say that diving in that spring-fed pool was a godsend in the tropics.

The most interesting thing about diving in my era – from wood through aluminium – was that we never knew what type board we were going to see at the site of the competition. In fact, in 1954 I attached a Jimmy Patterson board on the top of a station wagon and drove from Ohio State to Yale for the national indoor championships. I installed the board on the one-meter standard and won the event. However, I was not allowed to install it on the three-meter standard and I lost the event diving on a Buckboard!

For those who can last the length of the paper I hope that they, especially those who have always been on the Duraflex board diving into beautiful pools, have a greater appreciation of those who came before. I'm not complaining about what we went through, as I always loved to dive - no matter the conditions. And, we sure had fun!

Author and Acknowledgement to:

Bob Clotworthy, USA, 1956 Mens 3m Springboard Olympic Champion,

The End

APPENDIX B

A Classic Olympic Memory:

I have many wonderful memories of seven Olympic Games with one more, Beijing 2008, to come. If I were asked to choose just one it would be Matthew Scoggin of USA and he did not win a medal!

The Place: Barcelona

What: 1992 Olympic Games

Event: Mens' 10 metre Platform (Olympic Final).

After the roller coaster rides of the previous three finals the "big dipper" was about to start. The Blue Riband mens' 10 metre highboard final was the last event of a memorable 1992 Summer Games.

It was the only day that even the accredited TV commentators and journalists had to have tickets to enter the pool on Montjuic, arguably the most spectacular diving venue in the world. Who could forget the moving images of colour and grace as each diver caressed their flight down the canvass of the majestic backdrop of the old city below and the iconic Sagrada Família church, Gaudi's masterpiece.

From a Preliminary field of 24 athletes the 12 finalists lined up. The top seeds were Xiong Ni CHN, Sun Shuwei CHN, Jan Hempel GER & Scott Donie USA, Matthew Scoggin, USA. Ni was the diver who, at 14 years of age had taken the battle to the great Greg Louganis in the 1988 event at Seoul and which Louganis had won by the barest of margins (1.14 points). Here he was again 4 years older and tougher with his team mate Sun Shuwei, the 1991 World Champion.

It was to be an event dominated by the Chinese, or so we thought, and in part we were correct. What we did not foresee was the heights of excellence that the leading divers would push each other to; nor did we foresee the drama that would unfold.

Many were picking Jan Hempel of Germany to be in the money on his training form but who finished fourth, or Robert Morgan of Great Britain, The Commonwealth Champion of the time, who finished fifth or Scott Donie USA, who finished second, or Matt Scoggin USA who was looking really sharp in training.

The leader board kept changing at the end of every round as the fortunes of each athlete moved in subtle shifts of Degree of Difficulty. The pressure increased as each round progressed (10 in all) and one by one the less mentally tough, and those with slightly lower Degrees of Difficulty, began to drop off the pace and slide down to the bottom half of the field. Inexorably, by the start of the 7th round out of 10, the pressure on the leaders had been cranked up to an almost unbearable level. This was no place for the faint-hearted!

Scoggin of USA had started well and by the end of round 6 was in the leading trio. Four rounds to go and he was looking strong; not as strong as Shuwei but within striking reach of a medal. Then disaster struck. His 7th round dive was a high Degree of Difficulty backward 3½ somersault tuck. He jumped it up strongly and snapped into the rotating somersault movement, then all of a sudden his left hand slipped and came away from his left shin. The dive came apart dramatically as the centrifugal force opened him up and what had begun as copy book mechanics ended up in a 55kph flat on his back crash on the surface of the water.

Scoggin was hurt badly. After managing to exit the water he began jogging to his left and to the Referee with me assuming he was going to appeal for a redive. Suddenly he turned and continued to jog in the opposite direction. It suddenly dawned on me. The intense pain from the crash was such that to relieve it he was moving his body as one would shake ones hand after smacking with a hammer!

He had 12 minutes to recover before stepping up again for three dives. All hope of a medal had vanished. With that failed dive for zero points he was now at the bottom of the leader board.

His hope was to score the highest points possible with his last three dives and to avoid finishing last. He took his position on the highboard for the 8th time and punched a superb forward 3½ somersault pike for 8's & 9.5 points from the 7 judges. The spectators roared their approval and Scoggin had moved up into 11th place with two rounds to go.

Ninth round. An inward 3½ somersault. The entry went past vertical. It was slightly washed over and scored mediocre 6's. Still holding onto 11th place with one dive to go.

Last round. Scoggin took his position for the 10th and final time. The Referee gave him the whistle signal to start and the crowded stadium held their breath. This was not about winning a medal because there was no hope of that for Matt Scoggin. This was about personal courage and the honour of himself and his country.

The dive was the extremely difficult backward 1½ somersaults with 3½ twists. He jumped up strongly off the platform and initiated the first part of the somersault then snapped into the twisting movement. It looked very good. The stadium held its breath then Scoggin checked into a clean, crisp lineup and nailed the entry! That magnificent dive had taken a little over two seconds.

The packed stadium rose as one body. Cheers reverberated. Hats were tossed in the air. The applause was thunderous. Everybody understood that they had witnessed a unique Olympic drama and country affiliation was of no importance.

The judges awarded their marks; 9's from all seven judges and the stadium raised their cheers and applause to a new level.

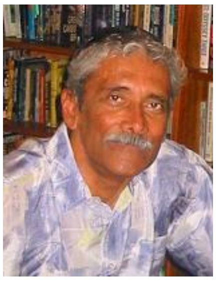
Matthew Scoggin, in a moment of great personal challenge and triumph, knew instinctively he must acknowledge the compliments of the packed stadium. He borrowed the gestures of the Asian divers. After exiting the pool underneath the 10m platform, framed by the towering structure to the sides and above him, he paused, turned and gently bowed to the crowded galleries, first to his right and then to his left, to acknowledge their salute.

Again the stadium erupted in response and Matthew walked off the pool deck to his coach, to his medics and into that part of Olympic history reserved for the courageous.

After the massive crash he fell from the second place to last. Injured by the horrendous impact on the water and with only three rounds remaining his final ranking rose from last, to eleventh to tenth.

This performance by Scoggin was in the true spirit of the Olympic Games and will remain with me for the remainder of my days.

Aquatic Rehabilitation and Water Exercises



Jan Prins, Ph.D.[1]

[1] Department of Kinesiology. University of Hawaii, Honolulu, Hawaii. U.S.A.

Introduction

The physical properties of water provide a unique environment for exercising to improving strength, flexibility, and cardiovascular conditioning. Although swimming has often been used for these purposes in the past, there is now an increased focus on incorporating specific exercise protocols in the water for treating persons with acute or chronic clinical conditions, as well as assisting persons with permanent physical disabilities (8, 9, 23, 24, 36, 38). The last few decades have also seen a dramatic increase in aquatic exercises to maintain overall fitness. These programs, referred to generically as "aquarobics," are not limited to the use of formal swimming strokes. Aquatic physical rehabilitation is now recognized and utilized as a "procedure," rather than a modality. The increased focus can be attributed in part to its evolution from the limited confines of "Hubbard Tanks," to the larger venues of swimming pools. These larger exercising areas accommodate a greater variety of exercises, including those that require sustained propulsive movements. In the same way, programs that promote adult fitness have gravitated to the water to the point that there are now a large number of aquatic routines directed specifically towards the aging population.

The focus of this presentation is to provide medical practitioners and allied health professionals with an overview of the benefits of aquatic physical therapy and water exercises. Also included in the discussion will be the application of the research tools used in biomechanics, which are used in the study of these disciplines.

Kinesthetics of Exercising in the Water

Most movements in the water are learned skills and take time to develop. Kinesthetic feedback in the water is subtle and, therefore, effective movement mechanics need to be developed and closely monitored. A person who has previous aquatic experience can be expected to begin water exercises or aquatic physical therapy with less apprehension than someone unfamiliar with the water. However, this experience can be an impediment to recovery because there remains the risk of counterproductive movements, or in the case of recovery from injury, utilization of previous patterns that may exacerbate symptoms and prolong the recovery period. The recommendation, therefore, is that participants in aquatic exercise programs and/or aquatic rehabilitation remain under the supervision of a trained clinician or specialist until they are able to continue independently with their routines, or transition to land-based physical therapy.

Physical Properties of Water

Two important physical properties of water, buoyancy and viscosity, are key elements in designing effective aquatic exercises. The advantage derived from buoyancy is direct; when a person enters the water there is an immediate reduction in the effects of gravity on the body. The viscosity of the water has an indirect advantage; when moving through the water, resistance is felt. The degree of effort is determined by the size of the moving body or limb, coupled with the velocity of the movement.

<u>The Force of Buoyancy and its Effect on Weight Bearing During Immersion</u>

The buoyant force of water decreases the effective weight of an individual in proportion to the degree of immersion. The ability to control joint compression forces by varying degrees of immersion is of primary benefit in the design and prescription of conditioning and therapeutic exercises. By monitoring the depths at which functional movements such as walking and stepping are performed, the effect of gravity can be re-introduced and, consequently, gradual strengthening is promoted (2, 9).

Axial loading on the spine and weight-bearing joints, particularly the hip, knee, and ankle, is reduced with increasing depths of immersion. When standing in chest-deep water the weight-bearing load is approximately 40% of the total body weight. Upon stepping onto a submerged step, the body is now at waist-depth, increasing the gravitational load to approximately 60% of body weight. When floating in the prone, supine, or vertical positions, the effects of gravity are, for all practical purposes, eliminated (17).

Because axial and compressive forces are reduced in the water, a case can be made for early prescription of aquatic therapy. When it is premature to resume full weight-bearing activities but important to beginning closed kinetic chain exercises, exercising in the water at graduated depths is ideal. Individuals recovering from shoulder, back, hip, and knee injuries and/or surgery can benefit from beginning therapeutic exercises in the supportive aquatic environment. Patients with multiple injuries also benefit from starting in the water. These patients can later transition to land-based physical therapy to continue their prescribed rehabilitation program (36, 42).

Muscle Strengthening using the Viscosity of Water

Although traditional modes of strength training are used successfully on land, there are advantages for using the resistance of the water to promote strengthening. Water acts as a variable "accommodating" resistance. The advantage of an accommodating resistance is that it matches the applied force or effort. Because the resistance of the water approximates the muscular force exerted, the probability of exceeding tissue tolerances is reduced and the likelihood of injury exacerbation dramatically reduced.

The term "variable" refers to being able to change the speed or velocity of the movement. Unlike isokinetic strength-training devices, which limit the effort to a pre-set velocity, it is possible in the water to vary the exercising limb speeds. Because most human motion is variable in nature, functional gains are more likely to occur when exercising in this manner (34, 35).

It is important to remember that strengthening exercises in water are limited only by the mobility of the joints being used. One limitation of conventional strength-training apparatus is that joint activity is isolated. Many exercise machines are designed with rigid bars that guide the motion of the metal plates that constitute the load This limits the user to exercising in fixed planes of movement (36). In contrast, strengthening exercises performed in the water can be designed to closely match functional movements and, as a result, provide neuromuscular adaptations better suited to activities of daily living. As a means of increasing the effort, resistive devices are commonly used when prescribing strengthening exercises in the water. These devices are available in a variety of shapes and sizes, each providing different amounts of frontal resistance.

Additional Advantages of Exercising in the Water

In addition to the above-mentioned factors, the properties of the water can be beneficial for other components related to exercise.

Using Buoyancy to Increase Range of Motion

Once immersed in the water, freedom of movement is enhanced. Early joint mobilization is more easily accomplished in the supportive environment of the water. By incorporating the effects of buoyancy, limb range-of-motion is enhanced beyond that which can be performed voluntarily on land.

Prolonged rest or inactivity following injury is no longer recommended for patient recovery. The inactive injured individual is predisposed to muscle atrophy, soft-tissue weakness, decreased joint mobility, and possible increases in pain. Consequently, early restoration of joint mobility has now gained acceptance, the therapeutic advantages of which are well documented. Functional deficits may also be addressed sooner with early mobilization (1, 19, 31, 38).

Cooperative Movements of the Extremities.

An often-overlooked advantage of aquatic exercise is the extensive range of available exercises that require alternating and/or symmetrical movements of the limbs and associated joints. These movements encourage increased involvement of the affected limbs by encouraging the injured side to match the effort and range of motion of the uninjured side. An example of this is the propulsive movement patterns of formal swimming strokes. This activity requires arm and leg action that combine symmetrical and/or alternating patterns of motion.

Cardio-respiratory Fitness in the Water

The loss of cardio-respiratory fitness can be significant during recovery from injury. Therefore, early resumption of exercise is now considered essential to the successful return to pre-injury activity. Aquatic therapy allows the injured person to begin exercising earlier. Aquatic running or jogging, when supported by a floatation device, offers additional benefits, most notably, the maintenance of rapid stride frequencies without the impact of landing, and coordinated movements between the arms and legs (5, 37). Deep-water running has been shown to compare favorably with land-based exercise. Maximum oxygen uptake (Vo2max) values for aquatic running ranged from 83–89% when compared to the values obtained from running on land. Maximum heart rate values for aquatic running ranged from 89–95% of values measured on land (40, 41).

Aquatic Exercise for Improving Muscular Endurance.

Insufficient muscular endurance, rather than insufficient strength, is now seen as the primary factor present in an individual’s inability to maintain the margins of safety of the spine, when performing the “activities of daily living”. Everyday tasks require repeated, low tension contractions and are interspersed only infrequently with efforts requiring high-tension contractions. Consequently, enhanced benefit can be expected from the prescription of routines involving moderate to high numbers of repetitions during early rehabilitation. Recent research shows that the ability to improve and maintain spine stability following injury requires low but continuous muscle activation (26-28).

Using the water as a venue for regaining function following injury is recommended for a number of reasons. The ability to minimize gravity-induced loading, coupled with the water providing an accommodating resistance, allows for the individual to increase muscular endurance without exacerbating the existing condition.

Social, Emotional, and Psychological Benefits of Aquatic Physical Therapy

Patient motivation and compliance with treatment are positive determinants for the success of any rehabilitation program. Studies report that patients who achieve even a modest recovery of their activities of daily living sustain their motivation to where they show demonstrable increases in endurance and strength (25). Because of the unique properties of water, aquatic physical therapy is an excellent rehabilitation choice, ensuring a high degree of compliance (2, 23). Because exercising in the water is enjoyable, patients are more likely to attend therapy on a regular basis and attain positive results sooner.

Recovery from Injuries to the Extremities and Spine.

The therapeutic advantages of exercising in the water for early restoration of joint mobility combined with progressive strengthening are well documented (4, 5, 10).

Upper Extremities & Spine

An array of clinical conditions such as subacromial bursitis, calcifying tendonitis, and partial rotator cuff tears are included in the term “frozen shoulder syndrome” (31). These conditions, which restrict active and passive glenohumeral motion, can be treated in water by taking advantage of the force of buoyancy to promote both active and passive movement. At present, exercises used in water for strengthening the cervical and thoracic regions are coupled with strengthening of the scapula stabilizers and glenohumeral musculature (18, 21, 31, 39).

Exercises can be performed in the primary planes of motion, diagonal pull patterns and sculling movements in oblique planes. An added advantage of the water is the ability to perform neck-strengthening exercises while floating in the prone position. When a mask and snorkel are used for breathing in the prone position, the buoyant force of the water can be relied on to support the weight of the head. This relieves injured muscles and associated soft tissue from the responsibility of counteracting anticipated gravitational forces (Figure 1).

Figure 1 (with permission from Prins Aquatherapy, Inc. 2007)

Although the treatment of lower back injuries can take various forms, a common goal is to increase strength and mobility of the weakened area. Because approximately half the weight of the body is above the injured area, spine patients are particularly susceptible to pain when performing activities of daily living. Being supported by the water while standing or walking at varying depths, alters the axial loading on the spine. Gravitational forces are also minimized when the patient assumes a prone or supine floating position. Swimming and kicking in the prone and/or supine body positions, utilizing the neutral spine concept and modifying stroke mechanics for individual patients (9).

When dealing with injuries to the spine, particularly the intervertebral disks, aquatic treatment must focus on effective spine stabilization protocols. Aquatic stabilization techniques help the patient regain dynamic control of segmental spine forces and eliminate repetitive injury to the motion segments. The effectiveness of aquatic spine stabilization exercises is based on the premise that in order for the upper and/or lower extremities to generate muscular forces, the axial skeleton, particularly the lumbar spine, must provide a stable base of support. This fulcrum or stable base is produced by isometric contractions of the abdominal and spinal muscles, with corresponding tension provided by the ligaments and associated structures, such as the thoraco-lumbar fascia (7).

Hip, Knee, and Ankle Injuries

When recovering from hip, knee and ankle injury, especially after surgery, the force of buoyancy can be used to decrease the weight of the body while promoting early ambulation. By monitoring the depths at which functional movements such as walking and stepping are performed, the effect of gravity can be re-introduced and gradual strengthening promoted (6, 10). Because joint reaction forces on the knee can reach several times body weight (15, 16), aquatic rehabilitation reduces the negative consequences of gravitational and compressive forces, allowing safe and effective therapy. Figure 2 shows step exercises that are performed starting at a weight-bearing load of approximately 40% (chest depth) and then raised to approximately 60% (waist depth) as the step is taken, (1).

Figure 2 (with permission from Prins Aquatherapy, Inc. 2007)

An 8-week study comparing aquatic physical therapy to traditional land-based therapy was conducted for patients recovering from ACL reconstructive surgery. Although no difference in passive range of motion was found between groups, the group treated in the water showed less joint effusion, greater self-reporting of functional improvement, and a record of higher scores on the Lysholm Scales, a measure of functional stability of the knee joint (39).

Treatment of Neurological Deficits, Diabetes, and Permanent Physical Disabilities

Neurological Deficits

Exercising in the water is recommended for persons with neurological deficits which may have developed as a result of a Stroke or cerebrovascular accident (CVA), tumors of the C.N.S., and conditions associated with progressive skeletal muscle dysfunction such as Multiple Sclerosis (5, 25). Buoyancy promotes movement of weakened muscles which under normal conditions cannot compete with gravity-induced loads. In the aquatic environment, it is easier to promote voluntary and involuntary movement and relearn essential motor skills such as walking. Because the density of water necessitates slower and more controlled movements, re-learning functional neuromotor patterns is facilitated by the hydrostatic pressure which increases proprioceptive and kinesthetic awareness (20). Individuals are also less apprehensive about practicing these skills in the water because the risk of injury from loss of balance is eliminated (12).

Studies have shown that when movement of one limb is compromised, the movement of the contralateral limbs will create a neuromuscular “cross-over effect” to the unexercised, homonymous, limb (14). Another benefit of the “cross-over effect” is the greater neuromuscular activity experienced by the non-exercising limb when it is placed in a specific position, particularly that of being supported (25).

A subtle but important benefit of aquatic motion for persons with neurological conditions, especially for those persons who have paralysis on one side of the body (hemiparesis), is the extensive range of available exercises that require alternating and/or symmetrical movements of the limbs and associated joints. These movements promote increased involvement of the affected limbs by prompting the injured side to try and match the effort and range of motion of the uninjured side (29, 30).

The Treatment of Arthritis and Diabetes by Exercising in the Water

Persons diagnosed with arthritis and diabetes are encouraged to participate in exercise programs to help control their disease and improve their general health. Warm water has traditionally been recommended for treating arthritis and the physical properties of water have been shown to alleviate the painful and weakened structures for individuals with this condition (3). Aquatic physical therapy is now also prescribed for diabetic persons. The water reduces the pressure-induced loads on the joints and consequently allows continued exercising with less risk of internal injury. However, indiscriminate participation in physical activities may compromise the health of both Type 1 and Type 2 diabetics because patients with these conditions are vulnerable to the stresses imposed by many types of activities (22).

Aquatic Exercises for persons with permanent physical disabilities

Aquatic exercise has been used extensively as a rehabilitative and therapeutic modality for individuals with permanent physical disabilities. The freedom of movement and the ability to exercise muscles which cannot overcome gravitational constraints make swimming and related aquatic activities invaluable for persons with a wide range of physically disabling conditions such as Amputation, Cerebral Palsy and Paraplegia (11, 13, 32).

Research in Aquatic Rehabilitation

By combining active physical therapy in the water with ongoing research in the biomechanics of aquatic motion, a multi-disciplinary approach to rehabilitation can promote the design of new equipment and the efficacy of treatment protocols. Examples of research include determining kinematic and kinetic changes as they relate to increasing mobility and relative strength during aquatic physical therapy.

As examples of the use of technology to monitor and evaluate progress we present the following two studies.

- Study 1: The use of underwater videography and motion analysis for evaluation of balance and proprioception can be a valuable tool. "Balance beam" and "Wobble-board" activities are commonly used in the rehabilitation of persons judged to be at a high risk of falling. These same activities can be performed in an aquatic environment to challenge balance and minimize the apprehension associated with falling. Underwater video analysis allows for objective assessment of body sway and loss of balance and strategies used for recovery (33). Figures 3a and 3b demonstrate measurement lateral displacement of skeletal landmarks (ASIS) during recovery of balance while balancing on the "Wobble Board".

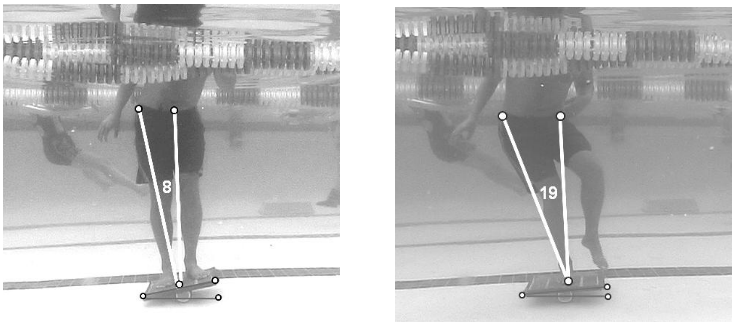


Figure 3a & 3b (with permission from Prins Aquatherapy, Inc. 2007)

- Study 2: A 79-year-old female was diagnosed with a fracture of the right olecranon process. As part of the treatment the patient was required to stand in the water at shoulder depth, hold a three-dimensional resistive device, and perform a "pull/push" action necessitating flexion & extension of the glenohumeral and elbow joints. To measure the applied force, instrumentation was developed comprising of silicon strain gauge sensors incorporated into a handle of the resistive device. A microprocessor integrated the sensor output, which was fed via a cable, to a laptop computer on which data was analyzed and displayed. Data was collected on three separate occasions during the treatment. Vector sums of the applied forces exerted by the injured and non-injured arms were recorded in Newtons for each exercise.

	Trial 1	Trial 2	Trial 3
Right Arm (injured)	0.35 N	0.86 N	1.65 N
Left Arm	0.92 N	1.80 N	2.17 N
% Strength Deficit	62.0%	52.2%	24.0%

The results shown in Table 1 reflect increases in applied force and the decrease in strength deficits between the injured and non-injured arm over time (34, 35).

Conclusions

Water provides an ideal environment for early recovery from injury. The reduction in gravitational constraints, coupled with the ability to regulate the intensity of muscular effort make it possible to perform sustained activity while reducing the risks associated with overuse. The water also provides a unique environment for promoting normal movement patterns and building strength in the early course of treatment of a wide range of clinical conditions.

References

1. Bates A, N. Hanson. *Aquatic rehabilitation of the shoulder.* Philadelphia: W.B. Saunders., 1996.
2. Becker BE, Cole Andrew J. . The future of aquatic rehabilitation. *J Back & Musculoskeletal Rehab* 4: 319-320, 1994.
3. Becker BE, G. Garrett. *Hydrotherapeutic Applications in Arthritis Rehabilitation*: Butterworth Heinmann, 2004.
4. Butts NK, M.Tucker , C.Greening. Physiologic responses to maximal treadmill and deep water running in men and women. *Am J Sports Med* 19: 612, 1991.
5. Cassaday SL, D.H. Nielsen Cardiorespiratory responses of healthy subjects to calisthenics performed on land versus in water. *Phys Ther* 72: 532, 1992.
6. Cavanaugh R, F. Warren, L. Day. A role of hydrotherapy in shoulder rehabilitation. *Am J Sports Med* 21: 850, 1993.
7. Cirullo JA. Aquatic physical therapy approaches for the spine. In: *Orthopaedic Physical Therapy Clinics of North America*, edited by J.A. C. Philadelphia: W.B. Saunders, 1994, p. 179.
8. Cole AJ. Aquatic Rehabilitation. *Annual Meeting, American College of Sports Medicine*, Dallas, Texas, 1992.
9. Cole AJ, M. Fredericson, J. Hohnson, M. Moschetti, R. A. Eagleston, S.A. Stratton. *Spine Pain: Aquatic Rehabiliation Strategies*: Butterworh Heinemann, 2004.
10. Croce P, J.R. Gregg. Keeping fit when injured. *Clin Sports Med* 10: 181, 1991.
11. Daly DV. Some criteria for evaluating swimming classification. *Adapted Physical Activity Quarterly* 16: 271-289, 1999.
12. Dean E, J. Ross. Modified aerobic walking program: effect on patients with post-polio syndrome symptoms. *Arch Phys Med Rehabil* 69: 1033-1038, 1988.
13. Dummer GM. Classification of swimmers with physical disabilities. *Adapted Physical Activity Quarterly* 16: 216-218, 1999.

14. Einarsson G. Muscle conditioning in late poliomyelitis. *Arch Phys Med Rehabil* 72: 11-14, 1991.
15. Genuario SE, J.J. Vegso. The use of a swimming pool in the rehabilitation and reconditioning of athletic injuries. *Contemp Orthopedics* 20: 381, 1990.
16. Gleim GW, J.A. Nicholas Metabolic costs and heart rate responses to treadmill walking in water at different depths and temperatures. *Am J Sports Med* 17: 248, 1989.
17. Harrison RA, M. Hilman, S. Bulstrode. Loading of the lower limb when walking partially immersed: Implications for clinical practice. *Physiotherapy* 78: 164, 1992.
18. Herbert R. Human Strength Adaptations - Implications for Therapy. In: *Key Issues in Musculoskeletal Physiotherapy*, edited by Crosbie J, McConnell, J. London, UK: Bitterworth-Heinnemann, 1993, p. 142-169.
19. Herbert R. Human strength adaptations: Implications for therapy. In: *Key Issues in Musculoskeletal Physiotherapy*, edited by Crosbie J. MJ. London: Butterworth-Heinemannn, 1993, p. 142.
20. Herbison GJ. Exercise therapies in peripheral neuropathies. *Arch Phys Med Rehabilitation* 64: 201, 1983.
21. Kibler WB. Role of the Scapula in the Overhead Throwing Motion. *Contemporary Orthopaedics* 22: 525-532, 1991.
22. Laughlin R, J.H. Calhoun, J.T. Mader. . The diabetic foot. *J Am Acad Orthop Surg* 3: 218-225, 1995.
23. Lawson GE. An overview of aquatic rehabilitation therapy. *Topics Clin Chiro* 3: 9, 1996.
24. LeFort S, T.E. Hannah. Return to work following an aquafitness and muscle strengthening program for the low back injured. *Arch Phy Rehabil* 75: 1247, 1994.
25. Levin S. Aquatic therapy. *Phys & Sp Med* 19: 119-126, 1991.
26. McGill SM. *Low Back Disorders: Evidence-based Prevention and Rehabilitation*. Champaign, IL: Human Kinetics, 2002.
27. McGill SM. Low Back Stability: From formal description to issues for performance and rehabilitation. *Exercise and Sports Science Reviews* 29: 26-31, 2001.

28. McGill SM, & Cholewicki, J. Biomechanical basis for stability: An explanation to enhance clinical ability. *Journal of Orthopaedic & Sports Physical Therapy* 31: 96-100, 2001.

29. Morris DM. *Aquatic Rehabilitation for the treatment of neurological disorders*: Butterworth Heinmann, 2004.

30. Morris DM, Jackson, J.R. Academic Programs Survey: Aquatic Physical Therapy Content in Entry Level PT/PTA Education. *Aquatic Physical Therapy Report* 1: 13-16, 1994.

31. Pearsall AW, K.P. Speer. Frozen shoulder syndrome: Diagnostic and treatment strategies in the primary care setting. *Med Sci Sports Exerc* 30 [suppl], 1998.

32. Prins JH. An analysis of basic swimming techniques with implications for designing rehabilitative and instructional programs for the physically disabled, edited by U.S. Department of Education WDC. Washington D.C.: National Institute for Disability & Rehabilitation Research, Office of Special Education and Rehabilitation Services, 1988.

33. Prins JH, Iris Kimura, Michael Turner, Matthew Weisbach, Lori Lehoullier The application of kinematic motion analysis in the evaluation of therapeutic exercises used in aquatic rehabilitation. *Arch Phys Med Rehabil*, 87, 2006.

34. Prins JH, J. Erickson. Measurement of applied muscular forces as a means of quantifying the resistances of selected apparatus used in aquatic rehabilitation. *IX th World Symposium on Biomechanics and Medicine in Swimming*, Univ. of St. Etienne, St. Etienne, France, 2002.

35. Prins JH, J. Erickson, J. Popovich, K. Kemp-Smith, D.A. Lally Measurement of applied muscular forces in aquatic rehabilitation. *48th Annual Meeting Of The American College of Sports Medicine*, Baltimore, Md, 2001.

36. Rivera JE. Open versus closed kinetic chain rehabilitation of the lower extremity: A functional and biomechanical analysis. *J Sports Rehab* 3: 14, 1994.

37. Svendenhag J, J. Seger Running on land and in water: Comparative exercise physiology. *Med Sci Sports Exerc* 24: 1155, 1992.

38. Tovin BJ, S.L. Wolf, B.H. Greenfield, J. Crouse, and B.A. Woodfin. Comparison of the effects of exercise in water and on land on the rehabilitation of patients with

intra-articuar anterior cruciate ligament reconstruction's. *Phys Therapy Forum* 74: 710-715, 1994.

39. Town GP, S.S. Bradley. Maximal metabolic responses of deep and shallow water running in trained runners. *Med Sci Sports Exerc* 23: 238, 1991.
40. Wilber RL, Moffatt, R.J., Scott, B.E., Lee, D.T., Cucuzzoo, N.A. Influence of water run training on the maintenance of aerobic performance. *Medicine and Science in Sports and Exercise* 28: 1056-1062, 1996.
41. Wilder RP, D.K. Brennan, D.E. Schotte. A standard measure for exercise prescription for aqua running. *Am J Sports Med* 21: 45, 1993.
42. Woolfenden JT. Aquatic physical therapy approaches for the extremities. In: *Orthopedic Physical Therapy Clinics of North America: Aquatic Physical Therapy*, edited by Cirullo JA. Philadelphia: W.B. Saunders, 1994, p. 209.

What is it important to know when using the critical velocity concept in swimming training?

PELAYO Patrick[1], ALBERTY Morgan[1], SIDNEY Michel[1], POTDEVIN François[1] and DEKERLE Jeanne[1, 2]

[1] Human Movement Studies Laboratory, University of Lille 2, France

[2] Chelsea School, University of Brighton, United Kingdom

Address for correspondence

Pr. Patrick Pelayo

FSSEP Lille 2, 9 rue de l'Université, 59790 Ronchin – France

email : patrick.pelayo@univ-lille2.fr

Tel : + 33 (0)3 20 88 73 51 or + 33 (0)6 75 66 21 38   Fax : + 33 (0)3 20 88 73 63

ABSTRACT

Because swimming coaches and scientists need to define accurately exercise intensity domains to optimize and evaluate aerobic and severe swimming training programs, the purposes of this review are to:

1. Review the recent studies conducted on the assessment and using of the Critical Swimming Speed (CSS) in order to well define the intensity domains and their boundaries.

2. Verify whether the speed corresponding to the slope of the distance-time relationship ($S_{d\text{-}t}$) in swimming is sustainable and represents the boundary between the heavy and severe intensity domains in swimming.

3. Assess whether intermittent swims at $S_{d\text{-}t}$ are tolerable and induce a physiological and psychological stress.

Key Words: *Swimming, Critical Velocity, Aerobic Intensity Domain*

Introduction

Recent studies on the energy system's contribution to maximal exercise have shown a higher aerobic contribution to the total energy demand than previously thought. This scenario has implications for all Olympic swimming distances. The assessment of swimmers' aerobic potential is fundamental in this sport to monitor training effects and prescribe training intensities. Swimmers' aerobic potential can be evaluated by measuring a single or several performances (concept of critical swimming speed: CSS related to *d-t* relationship), the performance of several sub-maximal constant-load tests (maximal lactate steady state), or an incremental test (ventilatory or lactate thresholds).

In order to optimise and evaluate aerobic and severe training programs the purpose of this paper is to review the recent studies conducted in swimming on the assessment of aerobic potential and using CSS. It is important that exercise intensity at critical speed have to be accurately defined and its physiological underpinning well understood. Indeed, each methodological approach should provide a useful index of aerobic potential, but they cannot be used interchangeably because they all represent different physiological entities. Indeed, the methods are associated with boundaries of several intensity domains whose characteristics differ according to physiological responses during exercise. The intensity domains have to be well understood and their boundaries accurately defined to optimize training programs and their assessment.

CSS has been defined as a sustainable and tolerable intensity above which fatigue and ensuing exhaustion would occur (Sherrer et al, 1960; Walsh, 2000). It should therefore be maintainable for a very long time with no major physiological or psychological stresses (Poole et al, 1998). It has been associated to the boundary intensity between the heavy and severe domain (Whipp, 1996; Poole et al, 1998). By definition, when exercising within the heavy domain, i.e. below CSS, capillary blood lactate concentration ($[La]_B$) as well as oxygen uptake (VO_2) would remain steady although the VO_2 would see its steady state being delayed (Whipp, 1996). When exercising within the severe domain, i.e. above CSS, drifts in $[La]_B$ and in VO_2 to VO_2max should be observed (Poole et al, 1998; Hill, 1999; Coast et al, 2003). Therefore, the anaerobic contribution should not progressively increase when exercising at CSS (Ferguson et al, 2007).

Thus, it is also important to know whether the speed corresponding to the slope of the distance-time relationship (S_{d-t}) in swimming is sustainable and represents the boundary between the heavy and severe intensity domains in swimming and to assess whether intermittent swims at S_{d-t} are tolerable and induce a physiological and psychological stress.

Empirical assessment of the two components of aerobic potential

Training programs aimed at improving the aerobic potential of swimmers are designed to increase the maximal oxygen uptake (VO_2max) and ability to utilise a high percent of the VO_2max for a long time (i.e., endurance; see (Bosquet et al 2000) for a review). To set training intensities, coaches traditionally use performances recorded during competitions to ease the screening of their swimmers (Smith et al, 2002). A 400-m performance is highly correlated to VO_2max in an heterogeneous-level group (Costill et al, 1985) and it has long been seen as a gold standard for estimating Maximal Aerobic Speed (MAS) and prescribe training intensities and an index of swimming level (Wakayoshi et al, 1993). The 1500-m performance, as the longest distance competitive event, could be seen as the second standard competitive test for profiling swimmers' aerobic potential. Alternative methods for aerobic endurance estimation, based on a single performance (2000 up to 3000-m; 30-min and 60-min tests (Madsen, 1982; Olbrecht et al, 1985), have been proposed in the literature (Costill et al, 1985). Indeed, the 400-m performance is not sufficient on its own to screen aerobic potential of a competitive swimmer. For example, two swimmers of identical 400-m personal bests could have different 1500-m times as a function of their different ability to utilise a high percent of their VO_2max over the race distance (i.e. different aerobic endurance capacities). Similarly, the variance between subjects 300-m and 400-m performances was better explained by an index of aerobic endurance than VO_2max (Cellini et al, 1986; Ribeiro et al, 1990). Therefore, to complete the assessment of a swimmer's aerobic profile, alongside a 400-m performance, a performance of longer duration should be recorded.

Critical Swimming Speed

In swimming, the modelling of the d-t relationship using a two-parameter model (*Equation 1:* $e = e_{anae} + \dot{e}_{ae}.\ t$) remains under debate. This is because it has to be assumed that the swimming energetic cost (Cs) is constant across the severe intensity domain (di Prampero, 1999). Equation 1 can then be divided by Cs, leading to a linear d-t relationship (*Equation 2 :* $d = ADC + CSS.t$). Rather, Cs increases with swimming speed (Capelli et al, 1998). Therefore, the d-t relationship might be distorted, and the speed corresponding to the slope of the d-t relationship ($S_{d\text{-}t}$) may not represent a CSS as previously thought (di Prampero, 1999). However, swimming literature reports very good fit of the relationship ($r<0.99$) between times (t) required to cover given distances as fast as possible (d), leading to a debatable conclusion that the 2-component model could be applied in swimming (Wakayoshi, 1992; Dekerle et al, 2002; Rodriguez et al, 2003).

The physiological responses at and around CSS during continuous exercise have never been investigated in swimming. It is still not understood whether S_{d-t} is related to CSS. If S_{d-t} was representing the speed that can be maintained relying solely on a maximal release of aerobic energy, swimming times at S_{d-t} should be of rather long duration (i.e. > 60 minutes) and the exercise tolerable. Since e_{anae} would not contribute to the supply of energy, capillary blood lactate concentration ($[La]_B$) should remain steady. According to the definitions of Hill and Ferguson (1999), if S_{d-t} was equivalent to CSS, VO_2max should be reached when exercising above S_{d-t}, but should not when exercising at and below this intensity. Only one study has examined the physiological responses during sets of four 400-m swims performed at and above S_{d-t} (Wakayoshi, 1993). The authors reported drifts of $[La]_B$ when swimming above but not at S_{d-t}, supporting S_{d-t} as a measure of CSS. However, the 30-45-sec break that enabled blood samples to be taken between the 400-m blocks could have enhanced lactate oxidation, limiting the drift in $[La]_B$ (Beneke et al, 2003). Later findings suggest that S_{d-t} is not an intensity swimmers could sustain for very long, and with blood $[La]_B$ steady state (Wakayoshi, 1993; Pringle and Jones, 2002; Dekerle et al, 2005). This would be in agreement with other reports in cycle ergometry (Dekerle et al, 2003) and treadmill (Smith and Jones, 2001).

The Maximal Lactate Steady State and the heavy intensity domain

Since speed is a ratio of distance over time, CSS is also represented by the time asymptote of the speed-time hyperbolic relationship. The CSS construct can be mathematically defined as the maximal speed that can be maintained, in theory, indefinitely. According to the concept, the anaerobic work capacity should only be utilised for the energy supply during exercise performed above CSS. Therefore, when exercising at CSS, blood lactate concentration ([La]) should remain stable. This is the result obtained by (Wakayoshi, 1993) whose swimmers were required to perform four 400m at CSS. However, the results of other studies do not support this finding. CSS has been shown in swimming to be higher than Maximal Lactate Steady State (MLSS) directly measured from the performance of several 30-min tests (Dekerle et al, 2005). Similar results have been obtained in cycling (Pringle and Jones, 2002) and running (Smith and Jones, 2001) suggesting that CSS overestimates MLSS, or alternatively these methods do not correspond to the same physiological entities.

According to VO_2 kineticists, MLSS (and not CSS) represents the boundary between the heavy and severe domain (Barstow, 1994). Above MLSS, drifts of blood [La], heart rate and VO_2 ('slow component') is observed, and exercise maintained up to an hour (exhaustion times usually recorded at MLSS). Capillary blood [La] could attain 8-10 mmol.L^{-1} (Brickley et al, 2002). However, because of the different definitions of the severe intensity domain depending on the model (the VO_2 kinetics, i.e. drift of [La] during exercise and VO_2 slow component; the CSS concept, i.e. attainment of VO_2max at the end of exercise), we suggest for now, to set a new domain between CSS (times to exhaustion of around 30 min) and MLSS (times to exhaustion of 60 min) called the "very heavy" domain. In this domain the drift of [La] is observed alongside a VO_2 slow component that doesn't reach VO_2max at the end of exercise. Clarity about this domain is needed in future experiments.

MLSS can be defined as the highest speed maintained with the highest stable [La] values resulting from a constant ratio between appearance and disappearance of lactate in and out the blood compartment (Beneke, 1995). Therefore, one method usually used by scientists to determine MLSS is based on [La] measurements at minute 10 and 30 of several constant intensity tests (Beneke and von Duvillard, 1996). The speed corresponding to MLSS is identified as the highest speed that can be swum with a drift lower than 1 mmol.L^{-1} between these two instants. Despite the substantial theoretical interest in using this method (accuracy), the requirement of performing several sessions of testing, and the collection of relatively few blood samples, lead physiologists to investigate the other possibilities to estimate MLSS more easily for coaches. An exercise performed at MLSS can be maintained for about an hour (i.e. the 60-min test of Madsen (1982). In swimming, MLSS is about 85% of the speed of a 400 m in trained swimmers (Dekerle et al, 2005) and corresponds to the speed a swimmer would spontaneously choose during the first 15 min of a 2-hour test (Baron et al, 2005).

MLSS has a real physiological meaning compared to CSS but is rather difficult to apply in the field. Its determination is based on a set criteria whose change could affect the MLSS value (Baron et al, 2003). Moreover, undertaking [La] measurement is not always practical, especially in populations such as children where the CSS determination could be more attractive (Greco et al, 2002; Toubekis et al, 2006). Furthermore, MLSS requires the performance of several 30-min swims, which can only be conducted in swimmers with a sufficient level of fitness.

***$S_{d\text{-}t}$* - CSS**

While some authors do not support the application of the critical speed concept in swimming (di Prampero, 1999), others have demonstrated its validity (Toussaint et al, 1998). No study has investigated the responses when exercising at and around the speed corresponding to the slope of the *d-t* relationship ($S_{d\text{-}t}$). The physiological responses when swimming above and below $S_{d\text{-}t}$ are also poorly understood. These questions need to be answered to provide a physiological description of $S_{d\text{-}t}$ in swimming, and assess whether or not this parameter corresponds to the boundary between the heavy and severe intensity domain.

Thus, the purpose of one of our recent study (Dekerle et al, in press) was to analyse the physiological responses when exercising continuously at and around $S_{d\text{-}t}$, It was hypothesised that $S_{d\text{-}t}$ would overestimate the boundary between the heavy and severe intensity domain, i.e. CSS.

Within a 3-week period, 9 trained front crawl competitive male swimmers performed a 100-, 200-, 400-, and 800-m all-out effort in a 25m indoor swimming pool in order to model the *d-t* relationship and determine $S_{d\text{-}t}$ and peak VO_2. They also swam in a randomised order constant speed efforts to exhaustion swum at and 5% above and below $S_{d\text{-}t}$ on different days. Capillary blood samples for measurement of $[La]_B$ were obtained from capillary blood samples taken from the finger-tip and Oxygen uptake (VO_2) was measured breath-by-breath with a portable automated system (K4b^2, Cosmed, Roma, Italy) during the first 30 seconds of the recovery period. Whole body RPE was recorded using the Borg 1–10-category scale (Borg, 1984).

$S_{d\text{-}t}$ could be maintained for 24.3 ± 7.7 min with an increase in RPE and $[La]_B$ ($P<0.05$), peak VO_2 being reached at exhaustion. Time to exhaustion (TTE) increased by two-fold when the speed was lowered by 5%; $[La]_B$, VO_2, and RPE remained stable. TTE dramatically decreased at S_{d-t} + 5% (8.6 ± 3.1 min), with end $[La]_B$ and VO_2 values of 10.2 ± 1.9 mmol.L^{-1} and 96 ± 7% of peak VO_2, respectively.

It can be concluded that swimming continuously at S_{d-t} would not be possible for a very long time, and would induce increases in $[La]_B$ and VO_2 responses, with end VO_2 values reaching their maximum.

Intermittent swims at S_{d-t}

In the previous study of Dekerle et al (in press), it was also hypothesised that $[La]_B$ would remain steady during a set of ten 400-m blocks swum at S_{d-t}. The same swimmers were also asked to swim ten 400-m blocks at their S_{d-t}. A 40-second break period enabled a blood sample to be taken after each 400m. RPE were also reported at the end of each 400m.

The results have shown that even if the RPE progressively increases, $[La]_B$ values remain stable during the 10 x 400-m blocks swum at S_{d-t}. This supports the hypothesis that 40s of passive recovery between 400m swum at S_{d-} enables the $[La]_B$ to remain stable. These results can be of great interest for coaches willing to work at maximal steady state in an attempt to improve muscular buffering capacities with training (Laursen, 2002). This might be achievable during long duration (and therefore volumes) sets of 400m swum at S_{d-t} as long as the passive recovery is of sufficient duration. These results are in accordance with those of Wakayoshi et al, 1992, 1993) reporting a $[La]_B$ steady state when swimming a 4 x 400m at S_{d-t} while a drift was observed when swimming 2% faster led to the conclusion that S_{d-t} was corresponding to CSS. It can be concluded that intermittent swims at S_{d-t} are tolerable but induce heavy physiological and psychological stresses.

Conclusion

Swimming coaches and scientists need to assess aerobic potential and define accurately exercise intensity domains to optimise and evaluate training programs. The speed corresponding to the slope of the *d-t* relationship (S_{d-t}) in swimming cannot be maintained for a long time and is hardly tolerable. It lies within the severe intensity domain. However, while S_{d-t} is not accurately representing CSS, it does demarcate two different intensity domains. The modeling of the *d-t* relationship in swimming can be of interest to depict intensity domains and set training intensities with some caution (di Prampero et al, 2008). The training effects when swimming at and below $S_{d\text{-}t}$ could be the focus of future investigations.

REFERENCES

Baron B, Dekerle J, Depretz S, Lefevre T, Pelayo P. Self selected speed and maximal lactate steady state speed in swimming. *J Sports Med Phys Fitness.* 2005;45:1-6.

Baron B, Dekerle J, Robin S, Neviere R, Dupont L, Matran R, Vanvelcenaher J, Robin H, Pelayo P. Maximal lactate steady state does not correspond to a complete physiological steady state. *Int J Sports Med.* 2003;24:582-587.

Barstow TJ. Characterization of VO2 kinetics during heavy exercise. *Med Sci Sports Exerc*. 1994;26:1327-1334.

Beneke R, Hutler M, Von Duvillard SP, Sellens M, Leithauser RM. Effect of test interruptions on blood lactate during constant workload testing. *Med Sci Sports Exerc.* 2003;35: 1626-1630

Beneke R, von Duvillard SP. Determination of maximal lactate steady state response in selected sports events. *Med Sci Sports Exerc.* 1996; 28: 241-246.

Beneke R. Anaerobic threshold, individual anaerobic threshold, and maximal lactate steady state in rowing. *Med Sci Sports Exerc.* 1995;27:863-7.

Borg GA. Psychophysical bases of perceived exertion. *Med Sci Sports Exerc.* 1982; 14: 377-381.

Bosquet L, Leger L, Legros P. Methods to determine aerobic endurance. *Sports Med*. 2002;32:675-700.

Brickley G, Doust J, Williams CA. Physiological responses during exercise to exhaustion at critical power. *Eur J Appl Physiol.* 2002;88:146-151.

Cellini M, Vitiello P, Nagliati A, Ziglio PG, Martinelli S, Ballarin E, Conconi F. Noninvasive determination of the anaerobic threshold in swimming: *Int J Sports Med.* 1986;7: 347-351.

Coats EM, Rossiter HB, Day JR, Miura A, Fukuba Y, Whipp BJ. Intensity-dependent tolerance to exercise after attaining VO2 max in humans. *J Appl Physiol* 2003; 95: 483-490

Costill DL, Kovaleski J, Porter D, Kirwan J, Fielding R, King D. Energy expenditure during front crawl swimming: predicting success in middle-distance events. *Int J Sports Med.* 1985;6:266-270.

Dekerle J, Baron B, Dupont L, Vanvelcenaher J, Pelayo P. Maximal lactate steady state, respiratory compensation threshold and critical power. *Eur J Appl Physiol.* 2003;89: 281-288

Dekerle J, Pelayo P, Clipet B, Depretz S, Lefevre T, Sidney M. Critical swimming speed does not represent the speed at maximal lactate steady state. *Int J Sports Med*. 2005;26: 524-530

Dekerle J, Sidney M, Hespel JM, Pelayo P. Validity and reliability of critical speed, critical stroke rate, and anaerobic capacity in relation to front crawl swimming performances" *Int J Sports Med.* 2002;23: 93-98

di Prampero PE. The concept of critical velocity: a brief analysis. *Eur J Appl Physiol Occup Physiol*. 1994;80: 162-164

di Prampero PE, Dekerle, Capelli C, Zamparo P. The critical velocity in swimming. *Eur J Appl Physiol*. 2008 ; 102:165–171

Greco CA, Bianco D, Gomide E, Denadai B. Validity of the critical speed to determine blood lactate response and aerobic performance in swimmers aged 10-15 years. *Science et Sports*. 2002;17:306-308.

Hill DW, Ferguson CS. (1999). "A physiological description of critical velocity" *Eur J Appl Physiol Occup Physiol* 79: 290-293

Laursen PB, Jenkins DG. The scientific basis for high-intensity interval training: optimising training programmes and maximising performance in highly trained endurance athletes. *Sports Med*. 2002;32: 53-73

Madsen O. Aerobic training: Not so fast there. *Swimming technique*. 1982;19:17-19.

Olbrecht J, Mader A, Madsen O, Liesen H, Hollmann W. The relationship to lactic acid to long-distance swimming and the 2 x 400m "2-speed test" and the implication for adjusting training intensities. In Ungerechts BE, Wilkie K, Reische K, ed. *Swimming Science V: Champaign, Human Kinetics books*. 1988;261-267.

Olbrecht J, Madsen O, Mader A, Liesen H, Hollmann W. Relationship between swimming velocity and lactic concentration during continuous and intermittent training exercises. *Int J Sports Med*. 1985;6:74-77.

Poole DC, Ward SA, Gardner GW, Whipp BJ. Metabolic and respiratory profile of the upper limit for prolonged exercise in man. *Ergonomics*. 1988;31: 1265-1279

Pringle JS, Jones AM. Maximal lactate steady state, critical power and EMG during cycling. *Eur J Appl Physiol*. 2002;88: 214-226

Ribeiro JP, Cadavid E, Baena J, Monsalvete E, Barna A, De Rose EH. Metabolic predictors of middle-distance swimming performance. *Br J Sports Med*. 1990;24:196-200.

Rodriguez FA, Moreno D, Keskinen KL. Validity of a two-distance simplified testing method for determining critical swimming velocity. In: *Biomechanics and Medicine in Swimming IX*. J. C. Chatard (Ed.) Saint- Etienne: University of Saint Etienne, 2003, pp. 385-390.

Scherrer J, Monod H. Le travail musculaire local et la fatigue chez l'homme. *Journal de Physiologie*. 1960 ;52: 420-501

Smith CG, Jones AM. The relationship between critical velocity, maximal lactate steady-state velocity and lactate turnpoint velocity in runners. *Eur J Appl Physiol Occup Physiol*. 2001;85:19-26.

Smith DJ, Norris SR, Hogg JM. Performance evaluation of swimmers: scientific tools. *Sports Med*. 2002;32:539-554.

Toubekis AG, Tsami AP, Tokmakidis SP. Critical velocity and lactate threshold in young swimmers. *Int J Sports Med*. 2006;27:117-123.

Toussaint HM, Wakayoshi K, Hollander AP, Ogita F. Simulated front crawl swimming performance related to critical speed and critical power. *Med Sci Sports Exerc*. 1998;30: 144-151

Wakayoshi K, Yoshida T, Ikuta Y, Mutoh Y, Miyashita M.Adaptations to six months of aerobic swim training. Changes in velocity, stroke rate, stroke length and blood lactate. *Int J Sports Med.* 1993;14:368-72.

Wakayoshi K, Yoshida T, Kasai T, Moritani T, Mutoh Y, Miyashita M. Validity of critical velocity as swimming fatigue threshold in the competitive swimmer. *Ann Physiol Anthropol*. 1992;11: 301-307

Wakayoshi K, Yoshida T, Udo M, Harada T, Moritani T, Mutoh Y, Miyashita M. Does critical swimming velocity represent exercise intensity at maximal lactate steady state? *Eur J Appl Physiol Occup Physiol*. 1993;66: 90-95

Walsh ML. Whole body fatigue and critical power: a physiological interpretation. *Sports Med*. 2000;29: 153-166

Whipp BJ. Domains of aerobic function and their limiting parameters. In: *The physiology and pathophysiology of exercise tolerance*. J. M. Steinacker and S. A. Ward (Eds.) New York: Plenum, 1996, pp. 83-89.

Overall training workout indicators of elite junior national waterpolo team: Serbian model for 2007 season

Milivoj Dopsaj[1, 2, 3], Nenad Vasilovski[2, 3], Nenad Manojlović[3, 4]

[1]Analysys and Diagnosis in Sports, Faculty of Sport and Physical Education, University of Belgrade, Serbia.

[2]Coach of youth and junior national waterpolo team of Serbia,

[3]Serbian Waterpolo Federation Expert Committee.

[4]General Manager of Waterpolo Association of Serbia.

The aim of this study was to define and specify the values of the indicators of overall training workout for the Serbian junior national waterpolo team in 2007 season, for the purpose of improving technology management. During the 90-day period between Jun 18, 2007 and Sep 15, 2007, the team had 75 pure training practice days with the total of 160 single training units, which included 88 training units in water, 41 training units outside water, and 31 games (where 8 were training games, 4 were official training games, and 19 were competitive games). In total, the team did 237 h 49 min of practice work, out of which 198 h 13 min were in the swimming pool (including the games) and 39 h 36 min were dryland work. Besides, the team members realised overall training load by swum total of 375.64 km (including the games), with an average of 3.157 km per single training unit. According to the time structure, players realised an average of 4 h and 6 min of training workouts per single training practice day, or 1 h 39 min 56 sec per single training unit in water (including the games days) and 57 min 57 sec per single training unit outside water. ITE index, the coeficient of pure training (practice) efficiency was at the index level of 0.3164 ± 0.1755.

Key words: *Training efficiency, water polo, training technology, training management*

INTRODUCTION

All trainers aim at helping the athletes or sports teams in their charge to be as highly successful in their competition field as possible. The quality of an athlete or a team is actually determined upon how successful they are in performing their sports activity, i.e. upon their efficiency. Therefore, efficiency is defined as the subject matter of training management (Милишич, 2007).

According to modern sports training theory, we can observe training as a complex and long-lasting cyclic adaptation process (Zhelyazkov & Dasheva, 2001; Bompa & Carrera, 2005; Platonov, 2007). A perpetual career-long training cycle is period of time which lasts approximately between 12 and 16 years, and with the most sucessful athletes it stretches over 20 years (Platonov, 2007). During this time, athletes pass through different phases in their biological development (physical, psychological, social, sport- and competition-oriented), which implies that the training should vary accordingly. In the function of a comprehensive development of an individual athlete or a team, the set variety of training phases show certain regularities relative to all aspects of sport training, such as, what overall amount of work and how many trainings can be realised during a season, what is the proportion among general, targeted and specific work, etc.

Therefore, modelling, i.e. its definition, constitutes an important part in the process of improving training technology, The procedure of defining a model requires precise description of the manifestations used by the coach in realising the training process. Thus certain variables help in quantitative description of measurable values that were used in training an athlete or a team with an aim to develop and advance the abilities required, such as physical, technical, tactical or psychological, which at a more general level constitute the competitive ability.

By thorough logical analysis of the realised single training load and by linking it to the achieved competition results, it is possible to define the most efficient training models, which enables a more complete control over the training process. An opportunity to gain fuller control over the training work leads the whole year-long training cycle from the stochastic level of probability-based systems to the deterministic level of a fully-controled system with a certain outcome (Милишич, 2007).

The aim of this study was to define and specify values of indicators of overall training workout for the Serbian junior national waterpolo team in 2007 season, for the purpose of improving technology management. In practice, our results can be treated as the training Junior European Champion Model.

METHODS

Descriptive and structural analyses were done for the whole preparation, pre-competitive, and competitive periods covered by the Serbian junior national team in 2007 season by using the standard metrological procedures according to Zatsiorsky (1982).

Throughout the study period we observed the training workout of 16 players with the following characteristics: Ages = 18.4 ± 0.6 yrs; BH = 190.2 ± 3.5 cm; BM = 87.6 ± 9.2 kg; BMI = 24.2 ± 1.8 kg/m^2; Training experience = 9.5 ±1.6 yrs.

During the whole training period for the Serbian national junior water polo team for 2007 season, all training data were entered in specially developed computer programs, and then daily analyzed according to the following:

1. training frequency as the number of single training units in a period of time (as water training, and as land (gym) training),
2. single training load realised during a single water training, as a distance in m, and as a time interval in h,
3. training load realised during a single land training, as a time interval in h,
4. training work load structure, defined in the function of 6 intensity zones, as follows: 1). AER I, low aerobic intensity – recovery (regeneration) type of training work load (HR under 150 Hz/min); 2). AER II, middle and high aerobic intensity – the type of training work load that maintains aerobic ability (HR between 150 – 165/170 Hz/min); 3). AER III, sub maximal and maximal aerobic intensity – the type of training work load that develops aerobic ability (HR between 165/170 – 175/180 Hz/min); 4). ANAER II, low and middle anaerobic intensity – specific anaerobic tolerance training work load (blood La between 5 to 8 mmol/L); 5). ANAER I, high level (sub maximal and maximal) anaerobic intensity – the type of training work load that develops anaerobic ability (blood La over to 8/10 mmol/L); 6). SPEED, maximal speed intensity – developing speed (anaerobic alactic i.e. CP energetic system) intensity,
5. training work load structure, defined in the function of the motoric stereotype, i.e. motoric character of work in 3 zones, as follows: 1). general work – (swimming); 2). targeted work – (simulation motoric tasks and technical tasks with the ball), 3). specific work – (game and part of game, i.e. extra and man less),
6. training work load structure, defined in the function of water polo elements, i.e. the specific motoric stereotype, divided in 5 characteristic groups, as follows: 1). technique of receiving and passing ball, 2). technique of specific water polo swimming, 3). shooting technique, 4). extra and man less, 5). full water polo game.

7. Moreover, a coefficient of training efficiency was calculated for each single training and the training cycle, as a qualitative indicator of the training work load applied, by the use of the following formula:

$$ITE = AER\ III + ANAER\ II + ANAER\ I + SPEED^{-\text{Single training load}}$$

where: ITE – represents the Index of Training Efficiency, in %; AER III + ANAER II + ANAER I + SPEED and Single training load, are in m.

RESULTS AND DISCUSSION

Table 1 shows the overall of the work load (including competitions) realised during the 90-day period between Jun 18, 2007 and Sep 15, 2007 for Serbian national water polo junior team.

Table 1. SERBIA – National Waterpolo Junior Team Competition season 2007, realised training data

Training Period	Training Cycles	Dates	Days of Training	Places	Training in the water (pool)	Unofficial Training games	Official Training games	Competition games	Dry training (Gym)	Sum	Σ Sum
Basic preparation period	Pre - Basic preparation cycle	18.06. – 03.07.07	14	Belgrade , SRB	23				9	***32***	**72**
	Competition I Balkan Games	04.07 – 07.07.07	4	Bukurest, Romania	3			4		***7***	
	Basic preparation cycle I	10.07. – 17.07.07	8	Kikinda, SRB	13				11	***24***	
	Basic preparation cycle II	19.07. – 22.07.07	4	Trieste, Italy	2	2	2		3	***9***	
			30		**41**	**2**	**2**	**4**	**23**		
Pre competitive period	Basic precompetition preparation cycle	25.07. – 05.08.07	11	Belgrade + Obrenovac, SRB	15	3	2		8	***28***	**49**
	Regeneration cycle	08.08. – 11.08.07	4	Belgrade, SRB	6				3	***9***	
	Taper I	13.08. – 17.08.07	5	Long Beach, USA	6	3			3	***12***	
			20		**27**	**6**	**2**		**14**		
Competitive period	Competitive cycle I, ***World Junior Championship***	18.08. – 26.08.07	9	Long Beach, USA	2			9	2	*13*	**39**
	Regeneration cycle	31.08. – 04.09.07	4	Belgrade, SRB	6				2	*8*	
	Taper II	05.09. – 08.09.07	4	Belgrade + MALTA	6					*6*	
	Main competitive cycle – ***European***	08.09. – 15.09.07	8	MALTA	6			6		*12*	
			25		**20**			**15**	**4**		
		18.06. – 15.09.2007	***75***		***88***	***8***	***4***	***19***	***41***		***160***

Table 2 shows the results of the analysis relative to training work load in water and on land.

Table 2. SERBIA – National Waterpolo Junior Team Competition season 2007, realised training data for overall load and training time parameters

					Pool training				Gym training		
Training Period	Training Cycles	Dates	Days of Training / Training in the pool + all games	Places	AVG per Training – time (h:min:s)	SUM of Training time (h:min:s)	AVG single unit Training load distance (m)	SUM Training distance (km)	Dry training (Gym)	AVG per Gym Training – time (h:min:s)	SUM of Gym Training time (h:min:s)
Basic preparation period	Pre - Basic preparation cycle	18.06. – 03.07.07	14 / 23	Belgrade, SRB	1:42.47	39:24.00	3607	82.96	9	0:57	8:41.00
	Competition I Balkan Games	04.07 – 07.07.07	4 / 7	Bukurest, Romania	1:22.43	09:39.00	2240	15.68	/	/	/
	Basic preparation cycle I	10.07. – 17.07.07	8 / 13	Kikinda, SRB	2:19.14	30:10.00	3992	51.90	11	1:03.00	11:40.00
	Basic preparation cycle II	19.07. – 22.07.07	4 / 6	Trieste, Italy	2:00.10	12:01.00	3530	21.18	3	1:13.00	03:40.00
			30/49						**23**		
Pre competitive period	Basic pre competition preparation cycle	25.07. – 05.08.07	11 / 20	Belgrade + Obrenovac, SRB	1:58.25	39:29.00	3980	80.59	10	0:59.20	09:02.00
	Regeneration cycle	08.08. – 11.08.07	4 /6	Belgrade, SRB	1:38.50	09:53.00	3302	19.81	3	0:53.00	02:39.00
	Taper I	13.08. – 17.08.07	5 / 9	Long Beach, USA	1:24.27	12:40.00	2772	24.95	3	0:35.20	01:46.00
			20/35						**14**		
Competitive period	Competitive cycle I, ***World Junior Championship***	18.08. – 26.08.07	9 / 11	Long Beach, USA	1:25.44	15:43.00	2414	26.55	2	0:31.00	01:02.00
	Regeneration cycle	31.08. – 04.09.07	4 / 6	Belgrade, SRB	1:22.47	12:25.00	2691	24.22	2	0:33.00	01:06.00
	Taper II	05.09. – 08.09.07	4 / 6	Belgrade + MALTA	0:53.20	02:40.00	1663	4.99	/	/	/
	Main competitive cycle – ***European***	08.09. – 15.09.07	8 / 12	MALTA	1:10.45	14:09.00	1984	23.81	/	/	/
			25/35		**1:39.56**	**198:13.00**	**3.157**	**375.64**	**43**	**0:46.07**	**39:36.00**
		18.06. – 15.09.2007	***75/119***		**Sum of 237:49.00 h of training**				**4:06.00 AVG of daly training time**		

Table 3 shows the results of analyzing the training structure in the function of the specific motoric stereotype, i.e. the technique and tactics in water polo relative to training phases.

Table 3. SERBIA – National Waterpolo Junior Team Competition season 2007, realised training data for specific motoric stereotype exercises

		Training work amount time parameters (in h:min)						% of training						
Training Period	Training Cycles	Technique of Receiving and Passing ball	Technique of Specific Waterpolo Swimm	Shooting Tecnique	Exta / Man Less	Full Water Polo Game	Σ	Technique of Receiving and Passing ball	Technique of Specific Waterpolo Swimm	Shooting Tecnique	Exta / Man Less	Full Water Polo Game	Σ	Basic swimm / Water polo specific (%)
Basic preparation period	Pre - Basic preparation cycle	0:08	0:26	0:04	0:02	0:07	0:41	7.21	25.28	3.54	1.72	5.94	43.68	56.32
		3:14	10:09	1:34	0:52	2:52	15:49							
	Competition I Balkan Games	0:07	0:10	0:06	0:06	0:25	0:31	9.87	12.93	8.54	7.82	28.57	67.73	9.87
		0:55	1:14	0:47	0:42	3:00	3:38							
	Basic preparation cycle I	0:18	0:23	0:19	0:19	0:08	1:20	13.19	17.01	14.2	12.81	6.19	63.39	36.61
		3:57	5:06	4:14	4:09	1:49	17:27							
	Basic preparation cycle II	0:07	0:12	0:09	0:21	0:35	0:51	5.76	13.84	7.04	16.50	26.78	69.92	30.08
		0:44	1:16	0:57	2:11	3:31	5:08							
AVG		***0:10***	***0:18***	***0:10***	***0:12***	***0:19***	***0:51***	***9.01***	***17.27***	***8.33***	***9.71***	***16.87***	***61.18***	***33.22***
		2:12	***4:26***	***1:53***	***1:58***	***2:48***	***10:30***							
Pre competitive period	Basic pre competition preparation cycle	0:13	0:09	0:11	0:19	0:25	1:17	9.73	7.53	7.78	15.59	21.50	62.13	37.87
		4:08	3:13	3:34	6:34	5:06	22:35							
	Regenerat. cycle	0:14	0:09	0:27	0:03	0:15	1:10	14.28	9.30	28.37	3.53	15.45	70.93	29.07
		1:25	0:55	2:45	0:22	1:33	7:00							
	Taper I	0:10	0:07	0:13	0:04	0:24	0:59	13.21	8.88	17.11	3.95	24.84	67.98	32.02
		1:34	1:05	1:59	0:37	3:36	8:51							
AVG		***0:12***	***0:08***	***0:17***	***0:09***	***0:22***	***1:09***	***12.41***	***8.57***	***17.75***	***7.69***	***20.60***	***67.01***	***32.99***
		2:22	***1:44***	***2:46***	***2:31***	***3:25***	***12:48***							
Competitive period	Comp. Cyc. I, ***World Jun. Champ.***	0:09	0:10	0:09	0:03	0:37	1:10	10.91	11.79	10.37	8.04	39.75	80.85	19.15
		1:44	1:52	1:42	0:42	6:51	12:51							
	Regenerat. cycle	0:13	0:13	0:09	0:08	0:03	0:48	15.82	15.94	12.28	8.79	3.17	56.01	43.99
		1:59	2:02	1:27	1:17	0:28	7:13							
	Taper II	0:11	0:15	0:14	0:03	0:00	0:44	21.28	28.24	26.17	6.41	0	82.10	17.91
		0:34	0:46	0:42	0:10	0:00	2:12							
	Main comp. cycle – ***European***	0:08	0:08	0:09	0:14	0:11	0:52	13.3	13.49	18.40	15.20	12.63	73.03	26.97
		1:36	1:43	1:59	2:49	2:19	10:26							
AVG		***0:10***	***0:12***	***0:10***	***0:07***	***0:13***	***0:54***	***15.33***	***17.37***	***16.81***	***9.61***	***13.89***	***73.00***	***27.01***
		1:28	***1:35***	***1:27***	***1:14***	***2:24***	***8:10***							
∑AVG per single period		**0:11**	**0:13**	**0:12**	**0:10**	**0:16**	**0:56**	**12.02**	**14.31**	**13.55**	**9.66**	**15.69**	**65.24**	**34.76**
	SUM according to TE-TA elements	21:50:00	29:22:30	21:40:00	20:25:40	25:58:33	119:16:43							

The results in Table 3 showed that the total time of training work load in the pool was 198:13:00 (hrs:min:sec), where 119:16:43 were in direct function of water polo game by the application of targeted and specific work (65.24 %), while 78:56:57 were spent swimming, that is, applying non-specific work (34.76 %). Out of this, the average of 5.89 % of the training was realised in Zone 6, i.e. in maximally intensified regime; which meant swimming 137 m (Maximal speed intensity), Zone 5 accounted for 4.41 % i.e. 111 m in high level anaerobic training intensity, Zone 4 acounted for an average of 6.45 % i.e. 163 m in low and middle level anaerobic training intensity, Zone 3 accounted for 21.34 % i.e. 542 m in sub maximal and maximal aerobic training intensity, Zone 2 accounted for an average of 26.52 % i.e. 662 m in middle and high aerobic training intensity, and Zone 1 accounted for an average of 27.07 % per training i.e. 714 m in low aerobic training intensity (Figure 1).

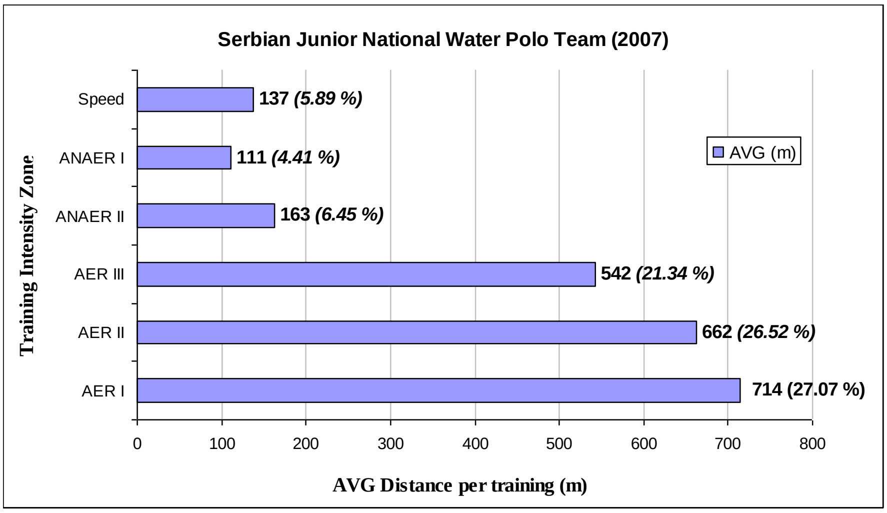


Figure 1. The averages of workload relative to the intensity zone in the whole training period observed (in m and in %)

Figure 2 shows the average values of Index of Training Efficiency (ITE) relative to the training cycles under analysis. The results showed that the highest average values of the index occurred in competition periods (Competition period I – Balkan Games, ITE = 53.53 %; Competition period II – Word Champ, ITE=53.02 %, and Comp period III i.e. main competition period – European Champ, ITE = 48.98 %). By contrast, the lowest index values occurred in both regeneration and pre-competition cycles, when the aim of training is to taper, that is, maximally reduce the amount of work at the expense of the intensity of work, in order to generally tone the body and provoke accelerated super-compensation of energy potential in athletes (taper period of training).

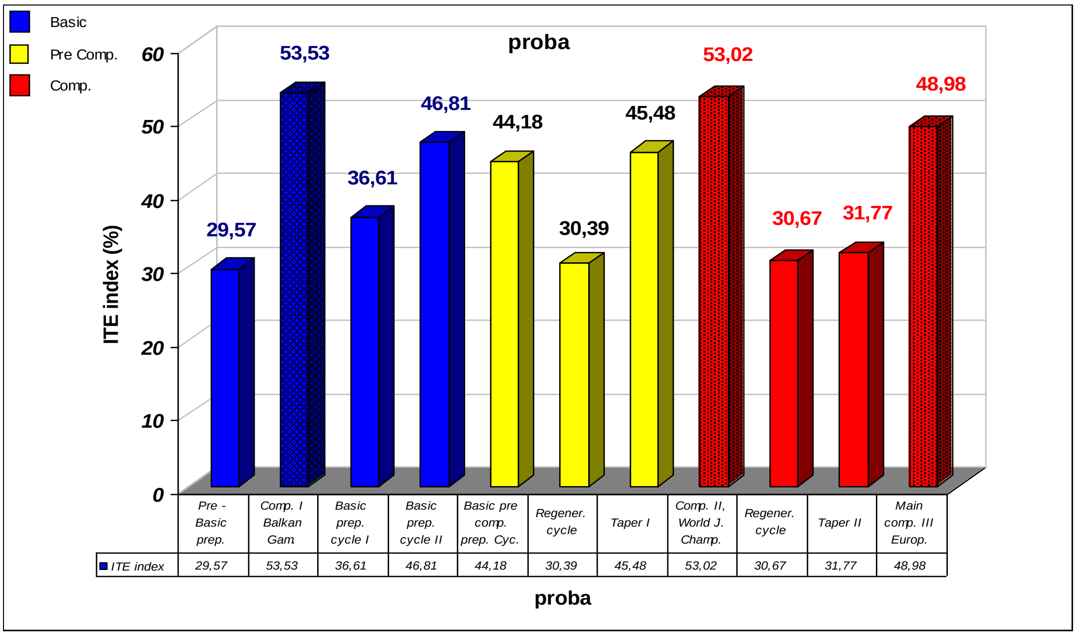


Figure 2. Index of Training Efficiency (ITE) average values relative to the analysed training cycles

CONCLUSION

The results of the analysis of 75-day pure training work with Serbian national water polo junior team enabled a description of the applied work model. During this period, the team realized 160 training units, out of which 88 were done in the pool, 41 in the gym, and 19 competitive games were played. Relative to time indicators, training work of 237 hours and 49 minutes (games included), with an average daily training of 4 hrs 6 min.

In view of motoric structure, i.e. how motoric activities were represented, an average of 65.24 % of the total work was in the direct function of water polo game, by the application of targeted and specific work (approx. 119 hrs 17 min), while approximately 79 hrs were spent swimming, that is, non-specific work was applied (34.76 %). ITE index, the coeficient of the pure training (practice) efficiency was at the index level of 0.3164 ± 0.1755.

At this moment, the results obtained in this study can be treated as Champion Model (the sample team became European Champions). However, future attention should be drawn to improving the technology of making top water polo teams by the definition of the same indicators for further categories of under-16s, under-20s and the best senior teams.

Moreover, the proposed model indicators will serve as future criterion indicators in comparison or correction of the existing training syllabuses, simultaneously improving the process of training junior water polo players.

REFERENCES

1. Bompa, T., Carrera, M. (2005). Periodization training for sports (Sec. Ed.). Champaign, IL: Human Kinetics.
2. Dopsaj, M., Matković, I. (1999). The structure of technical and tactical activities of water polo players in the first Yugoslav league during the game. Keskinen, K., Komi, P., & Peter Hollander, A (Eds.), Biomechanics and Medicine in Swimming VIII (pp. 435-438), Jyväskylä, Finland: Gummerus Printing.
3. Dopsaj, M., Thanopoulos, V. (2006). The structure of evaluation indicators of vertical swimming work ability of top water polo players. Portuguese J Sports Sci., 6(Supl. 2):124-126.
4. Dopsaj, M., Madić, D., Okičić, T. (2007). The assessment of the acquisition of various crawl style modes in water polo players with respect to age and competitive levels. FACTA UNIVERSITATIS Series: Physical Education and Sport, 5(2):109-120.
5. Милишич, Б. (2007). Управление тренировкой: Учебно-методическое пособие. Санкт-Петербург: Издательско-полиграфический комплекс „Олимп".
6. Platonou, T. (2004). Analysis of the "extra man offence" in water polo: A comparison between winning and losing teams and players of different playing position, J Hum Mov Studies., 46 (3): 205-211.
7. Platonov, V. (2007). Osnovne smijerice intenziviranja pripreme u procesu visegodisnjeg usavrsavanja. 5th International Conference "Kondicijska Priprema Sportasa«, 23 – 24. Veljaca, 2007, Zagreb, Croatia, pp. 24-31.
8. Takagi, H., Nishijima, T., Enomoto, I., Stewart, A. M. (2005). Determining factors of game performance in the 2001 world water polo championships. J Hum Mov Studies., 49 (5): 333-352.
9. Zhelyazkov, T., Dasheva, D. (2001). Training and adaptation in sport. Sofia: The Digital Document Company Xerox.
10. Зациорски, В. (1982). Спортивная метрология (Sports metrology). Москва: Физкультура и Спорт.

Invited Lecture

Japanese Session (Day4)

身体の発育発達と乳幼児の水中運動

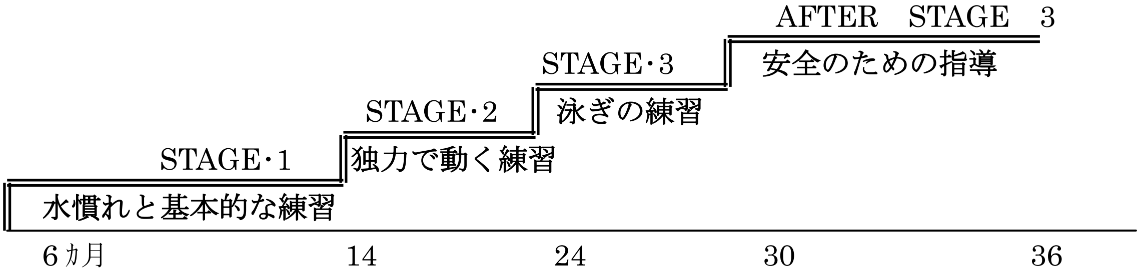
— Aquatic Readiness For The First Three Years —

ベビーエクササイズ指導普及の会代表　林　夕美子

1. 1990 年第 1 回世界ベビースイミング会議（World Aquatic Babies Conference）東京会場で、いくつかの重要な提案がありました。その一つアメリカの Stephan Langendorfer,PHD（Bowling Green State University）が「Aquatic Readiness を採用して安全で効果的な指導が行なわれるべきである」と発表しました。1973 年以来ベビースイミングクラスを開設・指導していた林は、既に発育発達と関連づけて指導書（0 才からの水泳指導　講談社 1979 年　等）を作成していました。そして満 7 ヶ月児～3 歳未満の子供達の動きを陸上の動きと水中での運動の比較をしながら Aquatic　Readiness を探ってみようとこのビデオテープを作成しました。このテープを、1995 年第 3 回 WABC メルボルン会議、1999 年第 5 回 WABC ツールーズ会議で発表しました。林は、乳幼児水泳クラスのインストラクター向けテキストの一つとしてもこれを使用しています。杉並区にあるススムアカデミーの生徒たち（週 1 回のレッスン）をモデルにして撮影しました。

（1）3 才児未満を 3 段階に分けています。

第 1 段階　生後 14 ヵ月未満
第 2 段階　生後 14 ヵ月以上 24 ヶ月未満
第 3 段階　生後 24 ヶ月以上 36 ヶ月未満



【　STAGE・1　】

水慣れと基本的な練習

※ 浅い所で遊ぶ
※ 背浮き、キック、プル、補助のもぐり

【　STAGE・2　】

独力で動く練習

※ 浅い所で水中歩行、お滑り台遊び
※ 水に飛込み、はい上がり
※ 背浮き泳ぎ、伏し浮き泳ぎ

【 STAGE・3 】	【 After STAGE・3 】
泳ぎの練習 ※ 息継ぎ、とびこみ、プル、キック ※ 背浮きに回転、伏し浮きに回転	**安全のための指導** ※ 飛込みからＵターンしてもどる ※ 水底のおもちゃを拾いあげる

(2) 月齢と陸上の動作・水中運動

① 生後 14 ヵ月未満の生徒　及び　4 ヵ月後、18 レッスン後

② 生後 14 ヶ月以上 24 ヶ月未満の生徒　及び　4 ヵ月後、14 レッスン後

③ 生後 24 ヶ月以上 36 ヶ月未満の生徒　及び　4 ヵ月後、15 レッスン後

2. ディニー・バン・ダイク女史の指導

7 ヶ月未満児の映像を補うために、ディニー・バン・ダイク女史のビデオも紹介します。ダイク女史は第 1 回 WABC 東京会議開催のために、実行委員長の林を積極的にサポートした人で、メルボルン市郊外で、3 つのスイミングスクールの経営者であり、指導者養成もしています。1993 年第 2 回 WABC ロサンゼルス会議で発表したもので、やはり Aquatic　Readiness を考慮して新生児から満 3 才までの親子指導を紹介しています。ここでは新生児から 1 歳までと 2 才半から 3 才までの水中運動及びスイミングの様子をご覧頂きます。ダイク女史の指導目標は、最終的に着衣して飛び込み、安全な背浮きになるまたは飛び込んだところにもどって這い上がることができるようになる事を目標としています。モデルはダイク女史のスクール週 2,3 回程度レッスンの親子です。

資料

水中毒事故と世界会議

1970 年代は、世界各国でベビースイミングが指導されその効果が注目されてきていたが、同時に悪い事故がアメリカで相次いだ。水中毒事件である。

水中毒とは、大量の水を短時間に飲んだことにより起こる病気である。具体的には、以下のような症状がみられる。不機嫌・興奮・ぐったりなどの神経症状、嘔吐、低体温、けいれん、意識障害。

そこで、これを憂慮したアメリカ小児科学会が、1983 年「３歳未満のスイミングを禁止する」という提言をした。この提言は世界各国の小児科学会に大きく影響した。日本でもＹＭＣＡを中心にこの提言が話題となった。その後７年間は、世界のベビーを扱うインストラクターが大いに悩んだ時期である。

話題を撒いたアメリカでは、この提言に対して、インストラクターと母親と発育発達の科学者達から猛烈な反発があり、実際には 1985 年　アメリカ小児学会が新たに提言を変更して、「ベビースイミングの指導には、潜らせる回数と時間、指導時間、レディネス（発育発達に沿った内容）を考慮した注意が必要である」とした。これを受けて、1989 年　ＮＳＳＡ（アメリカスイムスクール協会）ではガイドラインを作り所属するスイムスクールに通達及びセミナーを行なった。しかしこの新たな提言は、他の国々には伝わらず、相変わらず３才未満の指導に対しマスメディアがマイナス面を強調していた。

世界会議

ディニー・バン・ダイク女史の指導書を翻訳したことから親しくなった林夕美子は、ダイク女史と 1988 年メルボルン市で日豪インストラクター会議を開催、ベビースイミングの重要な意義を確認しあった。そして 1990 年東京で第１回の世界会議を開催、日本、オーストラリア、アメリカ、カナダ、スエーデンの発育発達の科学者と医師とインストラクターが水中毒事故と小児科学会の提言の実情と対策を検討した。参加者 400 名。

このとき世界会議は、２年ごとに開催されるよう次の当番国を決定した。

創始者のダイク女史と林は、アメリカのニューマン女史を加えて、第３回まで実行委員会の幹部委員として働き、その基礎を作った。メルボルン会議でこの３名の女史がその功労を讃えられ表彰された。

1993 年より会長国をアメリカがひき受け、実行委員は主催国の人達となっている。

世界会議 http://www.wabcswim.com は、WABC と略されている。1993 年に World Aquatic Babies Congress という名称にしたが、2007 年より World Aquatic Babies ＆ Children と改称された。

第１回会議　1990 年　東京（日本）

第２回会議　1993 年　ロスアンゼルス（アメリカ）

第３回会議　1995 年　メルボルン（オーストラリア）

第４回会議　1997 年　オハカ（メキシコ）

第 5 回会議　1999 年　ツールーズ（フランス）
第 6 回会議　2001 年　ブエノスアイレス（アルゼンチン）
第 7 回会議　2003 年　ワイキキビーチ・ハワイ（アメリカ）
第 8 回会議　2005 年　マルモ（スエーデン）
第 9 回会議　2007 年　セントピーターズバーグ（アメリカ）

WABC３歳児未満のガイドライン（2008 年現在）

1. 生徒の親にレッスンと水なれ指導について、その目標、指導テクニック、危険などについてあらかじめオリエンテーションをしておく事。
2. 安全で楽しい雰囲気で生徒が面白がる環境で指導され、グループ指導であろうと教師と１対１の指導であろうと、生徒１名に対し親または他の大人１名が指導する。
3. 乳幼児と子供の発育発達、指導法、水上安全を熟知した教師が常に新しい知識を吸収して指導すること。
4. 病気や障害のある生徒の親は、スクールに前もって相談しておかねばならない。レッスン前、レッスン中、レッスン後の注意を怠ってはならない。
5. 水温は 31℃～32℃と温かくする。
6. 水を汚さないように、生徒は少なくとも水着をつけること。
7. 水の衛生管理基準を守る事。
8. 初期の指導では、もぐりの練習は、1～3 秒に限定し、1 レッスン 5 回以内にする。1 レッスンは、30 分以内とする。慣れてくれば回数も秒数も増やす事ができる。

私の長距離選手の指導方法

田中孝夫（鹿屋体育大学）

はじめに

大学において課外活動を行う場合には，チームの活動目的を明確にし，どのようなチーム色に染めて行くかが，成否の鍵である。と考えている。そのため「競技力の向上と人格の形成」を鹿屋体育大学水泳部の活動目的としている。

その内容は，（ア）競技力の向上を図るためには.... 目標を持て，トレーニングを休むな頑張れ，ベスト記録を出せ（イ）人格の形成を図るためには...挨拶と「ホウレンソウ（報告・連絡・相談）と「ありがとうございます（感謝)」を忘れずに実行すること等々であるが学生が覚え易いように纏めているつもりである。その競技力向上と人格の形成を目的にトレーニングしている鹿屋体育大学の基本的な考え方とトレーニングの一端を紹介する。

トレーニング概念とトレニングレベル（強度)

トレーニング実施方法については，各コーチが自分なりの方法で成功を修めているのが実状であるが，鹿屋体育大学水泳部のトレーニングの大部分が漸進性の原則に則ったトレーニング方法を採用しており，特に持久力を高めるための有酸素的トレーニングは漸進性の原則に則ったトレーニングでその成果を挙げている。

一般的な有酸素性トレーニングは，AT-1(aerobic threshold:有酸素閾値)のトレーニングと AT(anaerobic threshold:無酸素閾値)のトレーニングによって実施されている。それに対して私達のチームの有酸素性トレーニングは，AT-1 と AT のトレーニングを，AT-1(有酸素閾値),AT(無酸素閾値のレベルの低いところ),AT+1(無酸素閾値のレベルの高いところ)に三分割して実施している。トレーニング内容は，漸進性の原則に則り後半の記録レベルを高めて行く方法である。基本的な実施方法は以下に示す。

AT-1(有酸素閾値)	AT(無酸素閾値)	一般的な方法

AT-1	AT	AT+1	鹿屋的な方法

また，目的に応じたトレーニングを実施するため，トレーニングレベルを設定しそのレベルでトレーニングメニューを作成する。私達のレベル（強度）は以下に示す通りである。

トレーニング強度　・距離　・効果

レベル　（表示）	心拍数等	距離	効果
１（有酸素)(－２)	110〜130	50〜800m	アップ効果
２（有酸素)(－１)	130〜150	50〜800m	持久力の維持
３（有酸素)(AT)	150〜170	50〜800m	持久力の向
４（有酸素)(＋1)	170〜180	50〜400m	持久力の向上
5（耐乳酸)(ＬA)	MAX	75〜300m	乳酸耐性の向上
６（無酸素)(AN1)	乳酸刺激	50m	スピードの維持
７（無酸素)(AN2)	乳酸刺激・産生	50m	スピードの向上
８（無酸素)(AN3)	乳酸刺激・産生	50m	スピードの向上
９（無酸素)(AN4)	非乳酸	25m以下	パワーの向上

測定項目と測定結果

選手の健康状態，トレーニング状況を把握しながらトレーニングを実施することにより，オーバートレーニングを防止し，トレーニング効果をあげることができる。また，測定したデーターを選手に情報提供することにより，トレーニング効果を数字または測定値で知ることができ，選手自身の具体的な体調管理，トレーニング目標，動機づけにもなることから，①ラクテートカーブテスト(200m×４回),②テスト2000(2000m泳),③スピードテスト（50×12×３セット）④血液検査，⑤最大酸素摂取量，⑥M・A・Dシステムによるプルのパワーと抵抗係数・指数の測定を年３回実施している。なお，④⑤⑥の内容については割愛する。

①ラクテートカーブテスト

運動レベルが高く，４０秒以上継続して行われるような場合には，乳酸を産生しその乳酸を利用しエネルギーを獲得する必要がある。また，そのような内容のトレーニングを行うことにより，乳酸に耐える能力が向上し，より乳酸生成が可能となる。そしてその蓄積に対して運動が制限されることを防ぎ，無酸素エネルギーの供給を可能にし，レース中より速く最大に近いスピードで比較的長い時間泳ぐ（100m〜400m を速く泳ぐ能力）ことが可能となる。日常のトレーニングによる乳酸耐性の向上を知る指針としてラクテートカーブテストを実施している。ラクテートカーブテストによるトレーニング効

果の評価方法として，スイム２００m×４回（－ ８’）の方法で実施。実施に際しては１回目８０％，２回目８５％，３回目９０％，４回目 MAX での測定とし，測定は記録，ストロークレート，血中乳酸，心拍数の４項目について実施した。なお，心拍数は直後に，血中乳酸は３分後の測定とした。

②テスト 2000

無酸素閾値は、400m かそれよりも長い距離に非常に大きな影響を及ぼすといわれている。そしてこれは，100m・200m のレースにも関係してくる。トレーニングの特殊性，加重負荷，負荷漸増の原則を無酸素閾値のトレーニングに応用するならば，乳酸除去の割合を向上させるトレーニングは，無酸素閾値のレベルよりも少し高い強度が効果的であると思われる。これは，強度のアシドーシスの害なしに，より急速に乳酸除去を起こさせる負荷を与えることになるからであると考えている。負荷漸増の原理を応用し，徐々にトレーニングのレベルを向上させると乳酸の蓄積は減少していくと考えられる。この無酸素閾値の測定方法は，血中乳酸から求める方法と呼気ガス代謝から求める方法が一般的であるが，我々は２０００m 泳から算出する方法を用いた。その理由として，無酸素閾値をトレーニングに採用する場合には，血中乳酸・心拍数・泳記録の３点から考える必要があり，より平常のトレーニングに近い形での測定が自然であるということと，2000m 泳記録を向上させることによって，無酸素閾値レベルの向上を知ることができる。言い換えれば 2000m の泳記録を向上させることによって無酸素閾値レベルを向上させることにも結びつくと考えられるからである。前半とばしすぎて後半へばらないこと，あるいは前半遅すぎて後半に力を残さないように注意し 2000m をほぼ全力で泳ぎ，記録・心拍数・血中乳酸を測定した。なお，心拍数は直後に，血中乳酸は３分後の測定とした。

テスト 2000 から推測されるトレーニング記録

上記 2000m 泳の平均記録から 50m から 400m までの AT レベルのトレーニング記録を決定した。なお，トレーニング記録の決定については，私達がこれまでのデーターから作成した下記，記録一覧表を参考に決定しトレーニングの目安として使用している。

100m 泳の平均記録	50m	100m	200m	300m	400m
1.05.0	30.50	1.04.0	2.12.0	3.19.5	4.28.0
1.05.5	30.75	1.04.5	2.13.0	3.21.0	4.30.0
1.06.0	31.00	1.05.0	2.14.0	3.22.5	4.32.0
1.06.5	31.25	1.05.5	2.15.0	3.24.0	4.34.0
1.07.0	31.50	1.06.0	2.16.0	3.25.5	4.36.0
1.07.5	31.75	1.06.5	2.17.0	3.27.0	4.38.0
1.08.0	32.00	1.07.0	2.18.0	3.28.5	4.40.0

③スピードテスト

50m×12 回×3 セットの記録を測定し，トレーニング効果としての基礎スピード能力の向上を知るための指標とした。水泳競技はスピードと持久力の双方を要するため，選手のスピード練習に対する動機づけ及びトレーニング効果の目安にもなる 。また，この能力（記録）が向上することにより無酸素パワー及びストロークテクニックの向上を推測することもできる。

測定方法は，１セット目は１分に１回，２セット目は１分１５秒に１回，３セット目は１分３０秒に１回の割合で泳ぎセット間の休息は，６分とし 200m のイージースイムを入れた。なお，心拍数は直後，3 セット終了後の乳酸値の測定は 3 分後の測定とした。

トレーニング記録から推測される泳記録

下記記録一覧は，前記スピードテストの結果により算出した大会における予想される泳記録である。１～３セットともに試合における泳記録との相関はあるが３セット目の記録が一番相関が高いことから３セット目の記録から試合における泳記録を推測するためのデータとして使用している。選手のタイプにより若干に違いがあるものの多くの平均的タイプの選手には，下記の大会における泳記録は十分参考になるものであり，私達のティームでは，記録測定と同時に大会における泳記録を推測するものとして使用し，それなりの効果を上げているのが実状である。

大会における泳記録

測定記録	(100m)	(200m)
26.00	51.50	1.53.00
26.50	52.50	1.55.00
27.00	53.50	1.57.00
27.50	54.50	1.59.00
28.00	55.50	2.01.00
28.50	56.50	2.03.00

競泳のトレーニングの３要素と５つのトレーニングポイント

速く泳ぐようになる。という目的を持ってトレーニングを行う場合，以下の 3 項目に注意したトレーニングを考える必要がある。

①抵抗の軽減　②運動効率(推進効率)を高める　③パワーの発揮能力を高めるの 3 点であるが具体的には以下に示す。

①抵抗の軽減

推進に必要なエネルギー（パワー）は，水の抵抗に打ち勝つために必要であり，抵抗そのものを減らすことができれば，同じパワーでもより速く泳ぐことができる。これは，主に水泳中の姿勢（フォーム）に関係する。水泳中の形状抵抗(全面造波抵抗)，渦巻き抵抗，粘性抵抗を如何に少なくするかが抵抗の軽減に結びつくと思われる。しかし，姿勢を変えることによって減らせる水の抵抗には限界がある。

②運動効率（推進効率）を高める

運動効率は，総エネルギー消費量のうち有効な仕事に要したエネルギーの割合を示す（機械的効率)。水泳の効率は３～１０％といわれ，走運動の４０～５０％に比べるとかなり低い。したがって，単に推進力の大きさのみに支配される運動ではないといえる。ストリームラインの形成による避抵抗技術，腕・脚による捕抵抗技術の向上により，推進効率を高めることが，水泳におけるもう１つの重要なトレーニングの目的である。しかし，推進効率を高めることにも限界がある。

③パワーの発揮能力を高める

身体が発揮できるパワー（スポーツでは，　負荷×スピード）を大きくできれば，最終的に推進に必要な力学的エネルギーも大きくできる。

水泳のトレーニングにおける最も重要な目的の１つは，身体の発揮するパワーの増加（スピード）と，それを定められた距離を泳ぐため持続する能力(持久力・スピード持久力)の獲得である。
競泳のトレーニングポイントは, ①避抵抗技術の向上　②推進効率の向上　③スピードの向上　④持久力の向上　⑤スピード持久力の向上である。この５つにポイントを絞ってトレーニングすることが競泳のトレーニングには必要なことである。

年間トレーニング計画

トレーニング計画は，毎年 9 月の日本学生選手権大会終了後，９月３０日までを休養期とし 10 月からトレーニングを再開している。翌年４月の日本選手権大会を目標として，スポーツフォームの発達周期性「形成・維持・消失」の考え方に基づいて，休養期，準備期，量的トレーニング期，質・量的トレーニング期，質的トレーニング期，調整期の６期に分けて目標大会までの流れを作っている。平成 19 年 10 月から 20 年 4 月の日本選手権大会までのトレーニング計画を以下に示す。

2007/9月〜2008/4月のトレーニング計画

9 月10日(月)〜 9月30日(土)休養期：3週間
10月 1日(月)〜10月27日(土)準備期：4週間
10月29日(月)〜12月22日(土)量的トレーニング期 :8週間
12月24日(月)〜 2月 9日(土)質・量的トレーニング期 ： 7週間
2 月18日(月)〜 3月22日(土)質的トレーニング期：6週間
3 月24日(日)〜 4月14日(月) 調整期　　：３週間
4 月15日(火)〜 4月20日(日)　日本選手権大会

各トレーニング期のねらい

①休養期

この期間の主な目的は，心身のオーバーホールにある。最近のスイマーは室内温水プールの普及により１年中泳げる環境にあり, この環境が水泳の記録向上の要因となっていることはいうまでもないことである。しかし，８歳から水泳選手になり２２歳（大学４年）まで，１４年間ほとんどトレーニングを休まずに継続するということはほとんど不可能に近いことである。もちろん，デイトレーニングによる休息期間の長さに応じた運動能力の低下は確実にあるが，その低下よりも，心身のオーバーホールと体の手入れが長期的にトレーニングを考えた場合に必要なことであると考える。

②準備期

休養期のデイトレーニングによる休息期間の長さに応じた運動能力の低下が確実にあり，いきなり従来のようなトレーニング内容を実施することは，不可能なことである。３～４週間程度の準備期間をとり，この期間に徐々にトレーニングの量と質を上げて行き時間をかけて体を適応させて行くことが必要である。この期間の主なトレーニング目的として以下のようなものが考えられる。

・徐々に練習量を多くしていき，泳ぎの感覚と身体的適応をはかる。
・ストローク技術の矯正と向上。
・４泳法のトレーニングによる水泳における全面的基礎体力の養成。
・次期の量的トレーニング期の練習に耐えるための持久力・体力の養成。

③量的トレーニング期

この量的トレーニング期は，文字どおり練習量（距離）を泳ぎ込むことにより，水泳選手としての持久力の向上と基礎体力の養成が目的であるため，トレーニングの内容は有酸素性運動を中心としたものとなる。この練習は，レース距離が長くなればなるほど大切な要素となる。練習は，距離を多く泳ぐ内容が中心となり，アシドーシスによる体の痛みを伴うような超ストレングスなものではないが，練習量が多くかなり苦しいという点においては，精神的・肉体的な苦しさがある。
この期間の主なトレーニング目的として以下のようなものが考えられる。
・全身持久力と筋持久力の養成・ストローク技術の矯正と向上。・スピードの維持

④質・量的トレーニング期

この質・量的トレーニング期は，前期量的トレーニング期に養成した循環器系機能の向上による全身持久力と筋持久力そして全面的基礎体力の向上を図りながら，次期の質的トレーニング期のレースに直結した，スピードとスピード持久力の向上を目的としたトレーニングを行うための移行期間としての考え方に立ったトレーニングを行う。したがって，そのトレーニング内容は，量的トレーニング期よりも若干練習量は少ないが質は高い。しかし次期，質的トレーニング期よりも練習量は多いが質は若干低いという中間的トレーニング内容となる。この期間の主なトレーニング目的として以下のようなものが考えられる。
・全身持久力と筋持久力の向上・スピード持久力の向上・ストローク技術の向上
・スピードの向上

⑤質的トレーニング期（長距離は質・量的トレーニングの継続）

この期の主なトレーニング内容は，前期（質量的トレーニング期）よりも，さらに一歩レースに向けて前進するため，より質の高いものとなる。メインセットのほとんどがレースを意識したものとなり，レースで記録を達成するためのコンディションづくりの仕上げのトレーニング期間といえる。

練習量は，前期と比較して若干少なくなるが練習内容をアップすることによる練習総量は，前期と同レベルかそれ以上となる。この期間の主なトレーニング目的として以下のようなものが考えられる。

・持久力の維持（長距離は向上）・スピード持久力の向上・スピードの向上

・ペースワーク・ストローク技術の向上・スタートターン等の技術向上

⑥調整期：十分な休養と心の準備

トレーニングによって，生体に刺激（運動負荷）を与えて器官や組織の機能を一時的に疲労させたのち，休息によって完全に回復すると生体の機能はもとの状態よも高い水準に達する。 超回復という生理学的原則にしたがって実施する。この期間の主なトレーニング目的として以下のようなものが考えられる。

・ストローク技術の向上　・持久力の維持　・スピードの向上

・スピード持久力の維持　・ペース感覚の修得・スタート・ターン等技術の向上

おわりに

泳法に基本があるように，トレーニングにも基本があると考えている。長距離選手のトレーニングは，絶対的な量が多いため選手は大変であると思うが，自由形長距離選手として記録の向上を図るためには，長距離選手のトレーニングの基本とも云うべき有酸素性トレーニングによって最大酸素摂取量の向上を図る必要がある。その最大酸素摂取量の向上を図るためのトレーニング方法は多種多様な方法があると思われる。

私達は，トレーニング科学から得た情報，水泳の知識，経験，感によってトレーニングメニューを作成しトレーニングし大会に出場している訳であるが，長距離選手の記録向上の観点から，そのトレーニング方法は効果的に実施しているのではないかと思っている。

【参考文献】

1）（財）日本水泳連盟編：水泳コーチ教本　大修館書店 東京　1993

2) E.W.マグリシオ: スイミングファースター. 野村武男他訳 ベースボールマガジン社 1986

3) E.W.マグリシオ: スイミングイーブン・ファースター. 野村武男他訳 ベースボールマガジン社 1999

4) 荻田太:競泳トレーニングにおける全身泳，部分泳の効用 競技力向上のスポーツ科学　トレーニング科学研究会編　朝倉書店　東京　1992

5) 荻田太:ピーキング　コンディショニングの科学　トレーニング科学研究会編　朝倉書店　東京 1995

6) 田中孝夫:速くなるためのトレーニング スイミングマガジン(12)　　1987

7) 田中孝夫:速くなるためのトレーニング　スイミングマガジン(1)　 1988

8) 若吉浩二: 最新の水泳トレーニング科学とメソッド　J.J.Sports Sci. 15　1995

9) （財）日本水泳連盟編: 新訂水泳指導教本 大修館書店 東京　1983

10) 宮下充正：トレーニングの科学的基礎 ブックハウスエイチディ 1993

Oral presentation

Day 2 – 26th March

Room 1 - (Hole 200)

Modelling leg movements and monofin strain towards increasing swimming velocity (Preliminary attempt)

Marek Rejman, Bartosz Ochmann
University School of Physical Education, Wroclaw, Faculty of Physical Education, Poland.

Key words: swimming, monofin, modelling, Neural Networks, kinematics.

The aim of the study was analysis of leg segments displacement and monofin strain in terms of propulsion efficiency. It was assumed that application of Artificial Neural Network enables precise determination of brackets within which the leg segments displacement and monofin strain will achieve optimal scope to gain maximal swimming speed. The response of network pointed 10 parameters. Those chosen to analysis are: foot flexion angle towards shin, proximal fin part flexion angle towards foot, attack angle of the distal fin part, attack angle of fin surface. Comparing network response graph with the results of the real movement analysis validates the results in the modelling sense. Vast network capabilities in developing the analysis with new cases allow for applying the model in monofin swimming technique assessment.

INTRODUCTION

The study is a stage of establishing efficient and economical monofin use in gaining maximal swimming velocity. The essence of monofin propulsion has been explained with the use of kinematic (1) and dynamic (2) analysis. Kinematic (3) and dynamic (4) criteria of the monofin swimming technique have been specified. Wu (5) among the others created models of the analysed technique. Only partial applicability of those works created a need for functional model of monofin swimming technique. Model construction is based on results generated by Artificial Neuronal Network (6). The utility of the Neural Network as a modelling method is based on the correlation between describing and described variables in dynamic processes of probabilistic nature. This makes it a useful tool in sport research. Neuronal Networks were used in modelling traditional swimming technique (7). Two-dimensional structure of propulsive movements where monofin is the only source of propulsion (4) facilitates modelling of the monofin swimming technique. Functional model of the monofin swimming technique (6) was represented by physical formulas and described the kinematic parameters and their combinations which determined the maximal monofin swimming speed in the aspect of using in the training technique.

The aim of the study is to develop functional model idea as a tool in monofin swimming technique assessment by assigning numerical form to certain technique parameters. Precise determination of optimal feet displacement and monofin strain points towards model aspect to increase monofin swimming efficiency. Optimisation criteria will be connected with propulsive movement modification to gain maximal speed during both movement cycle phases and in order to limit velocity decrease in the movement cycle. Gained high level of intra-cycle velocity stabilisation will create the basis for maximal swimming speed.

METHODS

The research was carried out in two stages. 11 volunteer male swimmers took part in both of them. They were 15-18 years old and displayed a high level of swimming proficiency. At the first research session swimmers swam 25m underwater at a maximum speed. At the second one they covered 50m. During both sessions the swimmers were filmed underwater, with the assumption that the swimmers move only on a lateral plane (2). Kinematic analysis of the movements was carried out using the SIMI® Analysis System (6). The results represented leg and monofin flexion angles and angles of attack of the monofin surface parts (and their derivations). The mentioned data were used as input variable for the Neural Networks. Horizontal velocity of the swimmer's body mass centre in a separated cycle was calculated. First 23 variables were used to define model relations against the output variable (Horizontal velocity of the swimmer) (6). After the second stage the input variables were reduced to 16 parameters pointed out by the network in the first stage. The network chose all of input parameters but only 10 were associated with monofin swimming speed. Following parameters were chosen to the further analysis on the account of significant influence on swimming speed and convenient measurement and interpretation: foot flexion angle towards shin (α_{ankle}) proximal fin part flexion angle towards foot (α_{tail}), angle of attack of the distal part (β_{distal}) and angle of attack of entire surface of the monofin ($\beta_{surface}$,).

The same procedure was employed for Artificial Neural Networks construction in both stages of modelling the monofin swimming technique. In the selection of a genetic algorithm Generalized Regression Neural Networks and Probabilistic Neural Network (8) were used. From several tested models the best model, with the fewest mistakes, was chosen. The model's development was based on multi-layer perception (9). The network's training process was based on a back propagation algorithm (10). Based on the training set the neural net model was constructed. The validation set was a basis for the network's "learning" results check. The testing set enabled assessment of network quality. For the preliminary interpretation of the network model, sensitivity analysis and regression statistics were used. Response graphs were used to graphically display particular correlations between input and output variables.

RESULTS AND DISCUSSION

Standard deviation values indicate the division boundaries within which angle changes regarding leg segments displacement and monofin strain take optimal values in terms of possibilities of gaining maximal swimming.

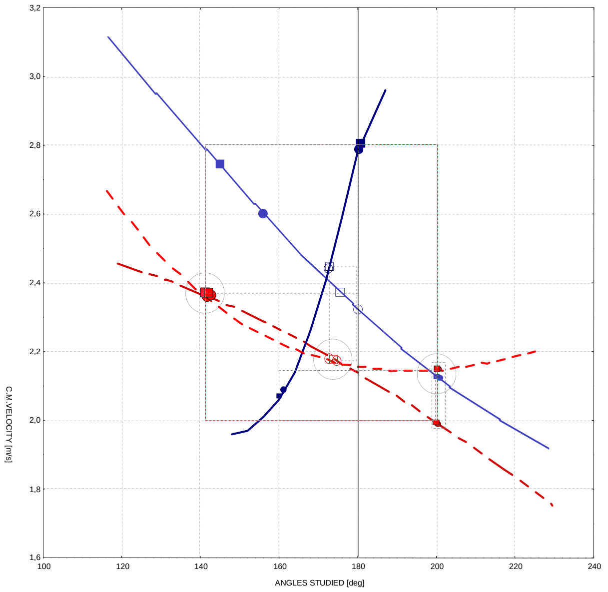


Figure 2. Network response graphs indicate division set by standard deviation values in which the examined angle parameters of leg segments displacement and monofin strain take optimal values in terms of gaining maximal swimming speed.

The same group of swimmers was examined in both stages of the experiment; in the same conditions with the use of the same research tools like Neuronal Network of identical construction. The network used in the present study generated very similar results indicating the same parameters as in the first version. The results of network answers (Figure 1) correspond with swimmer's movements record and its kinematic characteristics (Figure 2) Thus, there is a basis for verification of the applied method.

Results specifying optimal scope of feet displacement (α_{ankle}) signal that in order to gain maximal velocity during the upward movement phase it is essential to decrease the dorsal feet flexion (-20^{o}) from its parallel position towards the shin (180^{o}). Whereas during the downward movement plantar flex should not exceed 180^{o}. In both propulsive movement phases maximal swimming velocity corresponds with placing the monofin segments in one line at optimal attack angle. (Figure 2ACD).Thus, maximisation of the monofin surface at optimal attack angle decides about propulsion efficiency. Standard deviation values point at following optimal monofin segments strain: α_{tail} 35^{o} in the downward movement phase and (-)27^{o} in the upward movement phase, β_{distal}, $\beta_{surface}$, 37^{o} in the downward movement phase and (-)26^{o} in the upward movement phase.

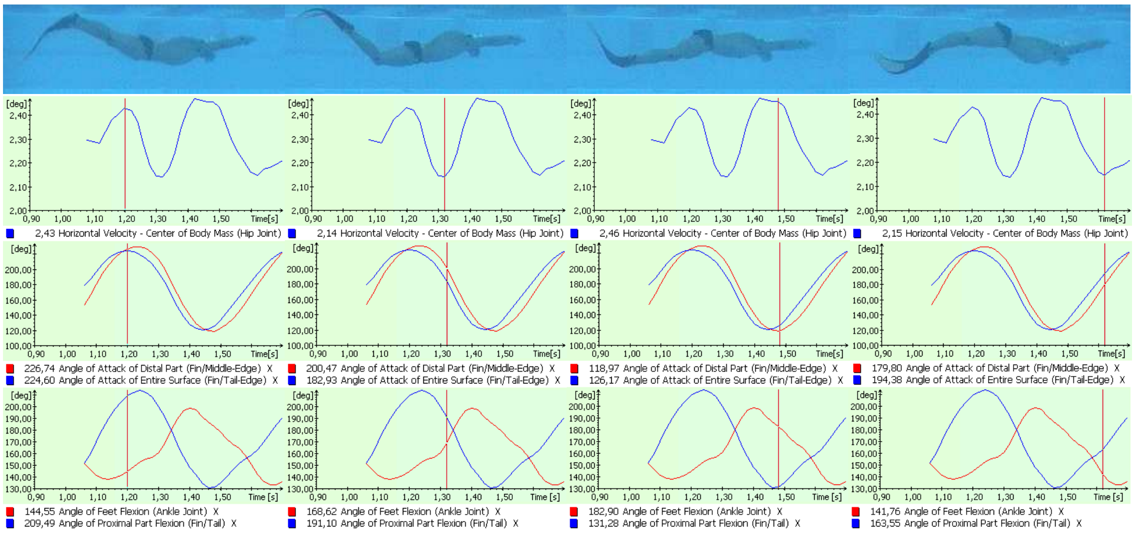


Figure 2. Real swimmer's movement illustration recorded during the research and corresponding characteristics of the analysed angle leg displacements and monofin strain in the fragments of movement cycle essential in terms of swimming velocity.

Results interpretation towards maintaining maximal velocity within the cycle requires from the swimmers earlier initiation of the feet upward movement (with knees straightened) in order to avoid parallel to swimming direction monofin position. The only way to maintain maximal velocity in the upward movement phase is optimal extension of leg lift time (with knees straightened) at optimal feet dorsal flexion.

Positioning the monofin at a proper angle of attack influences swimming speed. Comparison of the monofin and fish movements confirms the importance of lift and thrust in effective propulsion (11). In unsteady flow, the trajectory and the shape of the fin is dominated in inducing vortices (12). The angle of attack is an important factor determining the direction of movement of added water mass. When pushed backwards this creates an additional source of propulsion (1) favouring maintaining high swimming velocity. Minimal velocity in the subsequent cycle phases appear when the tail and the edge are connected with a straight line parallel to swimming direction (Figure 2BE). There is no basis to generate propulsion in such conditions. The least favourable monofin position from the propulsion efficiency point of view takes place during transition from upward to downward movement phase and vice versa (1). The minimal velocity in the movement phase is also the lowest velocity in the cycle. Unfavourable monofin position in this phase is accompanied by shin flexion at the knee joint which facilitates laminar water flow over the monofin. Additionally, upward shin movement (the same as swimming direction) arouses resistance.

Arellano (13) confirms suggestions as to velocity decrease limit in the movement cycle. He proved that as a result of undulatory movements accompanied by wave resistance, the shape of the fin surface changes, causing a negative phenomenon. In order to minimize this, it is necessary to minimize the amplitude of monofin movements while increasing stroke length. Minimising movement amplitude results also in reducing time of positioning the monofin in streamlined position. Delay in starting the knee flexion helps to minimise swimming velocity decrease in the upward movement phase (14).

Feet displacement and monofin strain in order to generate propulsion can be interpreted in analogy to fish movement. Eel-like movements are characterised by sinusoidal trajectory of all body segments displacement. (15). In model sense equal propulsion forces proportions are maintained during both cycle phases. (4). "Perfection" of fish swimming ability credits the postulate to optimise kinematic propulsive movement structure towards stabilisation of high intra-cycle velocity which is a condition to gain maximal swimming speed.

CONCLUSIONS

Reliability of the applied methods and reality of the results achieved on the basis of Artificial Neural Network justify model interpretation of the selected monofin swimming technique parameters. Large calculation network potential in developing the analysis with new cases is the point of departure for applying model solutions in monofin swimming technique assessment. The results focus on the need to minimise feet movement in the ankle joint during propulsive movements in order to maximise swimming speed. Monofin segments strains reduction during the downward movement and increasing the upward movement scope with straightened knees correlates with minimising propulsive movement amplitude. In such conditions there exists a basis to gain constant high intra-cycle velocity being the condition of maximal swimming speed.

REFERENCES

1. Colman, V., Persyn, U., Ungerechts, B.E. (1999) A mass of water added to swimmer's mass to estimate the velocity in dolphin-like swimming bellow the water surface. In: Biomechanics and Medicine of Swimming VIII. Eds: Keskinen, K.L., Komi, P.V., Hollander, A.P. Jyvaskyla: Gummerus Printing. 89-94.
2. Rejman, M., Colman, V., Persyn, U. (2003) The method of assessment the kinematics and dynamics of single fin movements. The Human Movements 2(8): 54-60.
3. Shuping, L., Sanders, R. (2002) Mechanical properties of the fin. In: Scientific Proceedings of XX International Symposium on Biomechanics in Sports. Eds: Gianikellis, K. Caceres. 479-481.
4. Rejman, M. (1999) Dynamic criteria for description of single fin swimming technique. In: Biomechanics and Medicine of Swimming VIII. Eds: Keskinen, K.L., Komi, P.V., Hollander, A.P. Jyvaskyla: Gummerus Printing. 171-176.
5. Wu Yao-Tsu, T. (1971).Hydrodynamics of swimming propulsion. Part 1. Swimming of a two-dimensional flexible plate at variable forward speeds in an inviscid fluid. J Fluid Mech 46: 337-355.
6. Rejman M., Ochman B. (2007). Functional model of monofin swimming technique based on the construction of neural networks. J Sports Sci Med 6(2): 193-203.
7. Edelmann-Nusser, J., Hohmann, A., Haneberg, B. (2001) Prediction of the Olympic competitive performance in swimming using neural networks. In: Annual Congress of the European College of Sport Science, Cologne: Cologne. Eds: Mester, J., King, G., Struder, H., Tsolakidis, E., Osterburg A. 328.
8. Speckt, D.F. (1991) A generalized regression neural network. IEEE Transactions on Neural Networks 2: 568-576.
9. Bishop, C. (1995) Neural networks for pattern recognition. Oxford, University Press.
10. Patterson, D. (1996) Artificial Neural Networks. Singapore: Printice-Hall.
11. Wolfgang, M.J., Anderson J.M. (1999) Near body flow dynamics in swimming fish. J Exp Biol 201:3143–3166
12. Ungerechts, B.E., Persyn, U., Colman, V. (1999) Application of vortex formation to self propulsion in water. In: Biomechanics and Medicine of Swimming VIII. Eds: Keskinen, K.L., Komi, P.V., Hollander, A.P. Jyvaskyla: Gummerus Printing. 95- 100.
13. Gavilán, A., Arellano, R., Sanders, R. (2006). Underwater undulatory swimming: Study of frequency, amplitude and phase characteristics of the 'body wave'. In: Vilas-Boas, J.P., Alves, F., Marques, A. (Eds.), Biomechanics and Medicine in Swimming X. Portuguese Journal of Sport Sciences, 35-37.
14. Rejman, (2006). Influence of timing delay on monofin intra-cycle swimming velocity. In: Vilas-Boas, J.P., Alves, F., Marques, A. (Eds.), Biomechanics and Medicine in Swimming X. Portuguese Journal of Sport Sciences, (6)2: 85-88.
15. Vilder, J.J. (1993) Fish Swimming. London: Chapman and Hall.

Study on Measurement of Propulsive Force under Feathering Motion of the Monofin

Hiroshi Tamura[1], Youzi Nakazawa[2], Takahiro Miwa[3], Takeo Nomura[4]

[1] Japan Underwater Sports Federation, Japan

[2] Total Fitness Club ACQUA SERENA, Japan

[3] University of Tsukuba, Graduate School of Comprehensive Human Sciences, Japan

[4] University of Tsukuba, Institute of Health and Sports Sciences, Japan

Finswimming competitions, in which swimmers compete wearing a mono-fin, are being held in many countries. The most exciting aspect of finswimming is its speed. We produced an experimental monofin which generate the maximum propulsive force most effectively. This study was noticed at the angle which wore monofin in an ankle especially. Propulsive force was measured using manufactured equipment. The effect of this wearing angle on the propulsive force was carried out. Simultaneously, the configuration of monofin which the most efficiently generated the propulsive force was studied. The percipient feeling evaluation of the swimmer was evaluated for six kinds of shapes. As the result obtained in this study, the most propulsive force is generated under up-kick motion in wearing the monofin to the position at α = -15°.

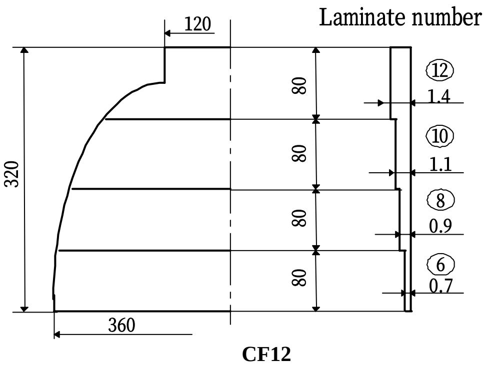
Key words: *Finswimming, Propulsive Force, Impulse, Momentum*

INTRODUCTION

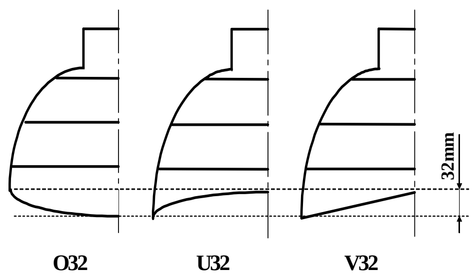
Finswimming competitions, in which swimmers compete wearing a monofin are being held in many countries. The most exciting aspect of finswimming is its speed. In Japan, Finswimmer is increasing every year for the attractiveness of this speed. This speed depends on the performance of the mono-fin that is one board worn to an ankle. Authors have carried out the engineering study, considering the future direction of fin swimming as the sport event, and the obtained result has been reported[1,2,3]. This study was especially paid to attention at the angle which wore the monofin in an ankle. The experiment wore the monofin to the manufactured test equipment, and measured the propulsive force generated under feathering motion. Also, the momentum was analyzed from this propulsive force. The influence on the wearing angle of the mono-fin was studied. Moreover, the mono-fin with six kinds of different shapes were manufactured. The effect of the shape on the generation of the propulsive force was experimented. Simultaneously, the percipient feeling evaluation by swimming of the test swimmer was also performed.

MATERIAL AND SHAPES OF MONOFIN

The material of produced monofin used the prepreg of 0.11mm thickness made from the carbon fiber. Monofin used for the experiment produced the fin of 1/2 size of the monofin used in the finswimming actually. The shape of the produced mono-fin is shown in Figure 1. The fin shown in (a) is the conventional monofin and 3 kinds shown



(a) Conventional monofin



(b) Produced monofin

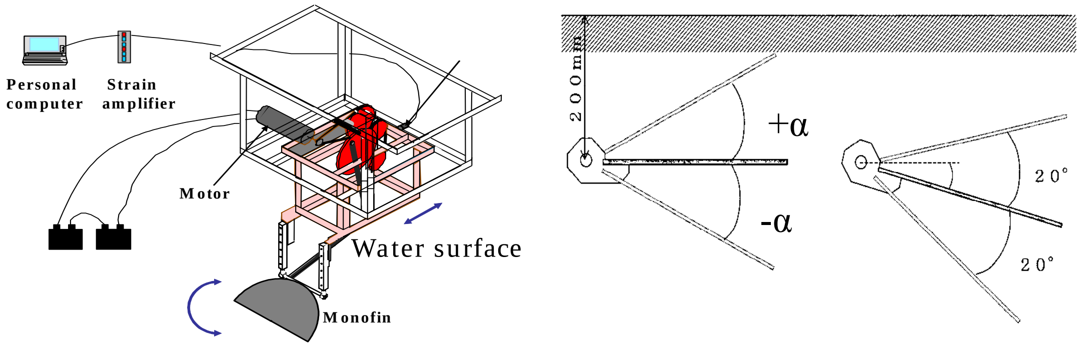
Figure 1. Shapes of monofin used for experiment.

in (b) were produced in order to examine whether it can the most efficiently generate the propulsion power. In other, monofin of 2 types which vertically and laterally strengthened the fin of one layer in order to utilize characteristics of the carbon fiber, were also produced. Each fin is composed of four layers; thickness is 0.7, 0.9, 1.1, and 1.4mm for every 80mm in length from the fin tip. The part was reinforced by the board of the CFRP in order to wear the boots made from the rubber in monofin.

PROPULSIVE FORCE MEASURING EQUIPMENT

The appearance in which the fin swimmer swam was observed it by the video. It became clear that the motion of the monofin is carrying out feathering movement. As the result, it was observed that the monofin which has worn at the ankle inclined toward downward. From this observation, it is important to study the effect of fin worn at the ankle on the propulsive force. Therefore, it manufactured the testing equipment which can simulate the condition which swims by finswimmer wearing on monofin at the ankle. This equipment can measure the propulsive force generated under feathering motion of the monofin. Schematic figure of the test equipment is shown in Figure 2(a). By wearing the monofin to the testing equipment, the feathering motion is carried out.

The main body moves on the outside frame by the force which generates at that time. It is detected in the load cell which installed the force as a necessity for this transfer in the outside frame, and the data is incorporated in the personal computer through the



(a) Manufactured equipment (b) Wearing angle α of monofin

Figure 2. Manufactured equipment and wearing angle α of monofin

strain amplifier. It was set so that drive period of the testing equipment may become 1.0 seconds in the condition without the monofin. And, the angle which wore monofin in the testing equipment was manufactured to be ±20°, sum total 40°.

EXPERIMENTAL METHOD

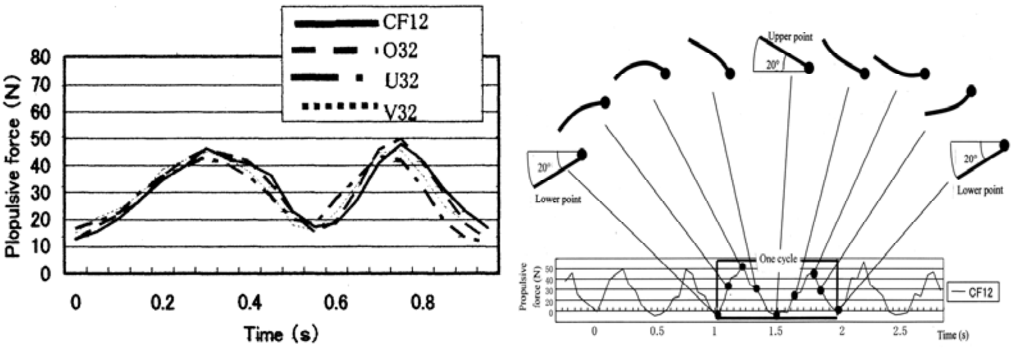
The testing equipment which wearing the monofin levelly was installed at the position of 200mm depth in the water tank of 3100mm length, 970mm width, and 2000mm depth. The monofin in the underwater is shown in Figure 2(b). The angle from the level to monofin is α. The propulsive force measured the force which generates from α=-20° to α=+20° in the movement of one cycle. The movement of the monofin from -20 ° to +20° is up-kick and reverse movement become down-kick. The experiment was carried out to increase α at each 5°, and the propulsive force under feathering motion from α=-15° to +15° was measured. The uptake of the data was started from the case in which there was a position of the monofin at the most lower end. Propulsive force averaged the date during feathering motion of 15 times

EXPERIMENTAL RESULTS AND DISCUTION

RELATIONSHIP BETWEEN PROPULSIVE FORCE AND WEARING ANGLE α=0°

The movement of the fin in one cycle and the propulsive force under up-kick by wearing monofin to the equipment at α=0°, is shown in Figure 3(a). Also, the movement under motion in one cycle of the monofin was shown in (b). The propulsive force which generates under the up-kick and the down-kick motion is same.

The most propulsive force is respectively generating at 0.25 second in the up-kick motion and at 0.75 seconds in down-kick motion. The position of the monofin in which this most propulsive force is generating approximately at α=±10°.

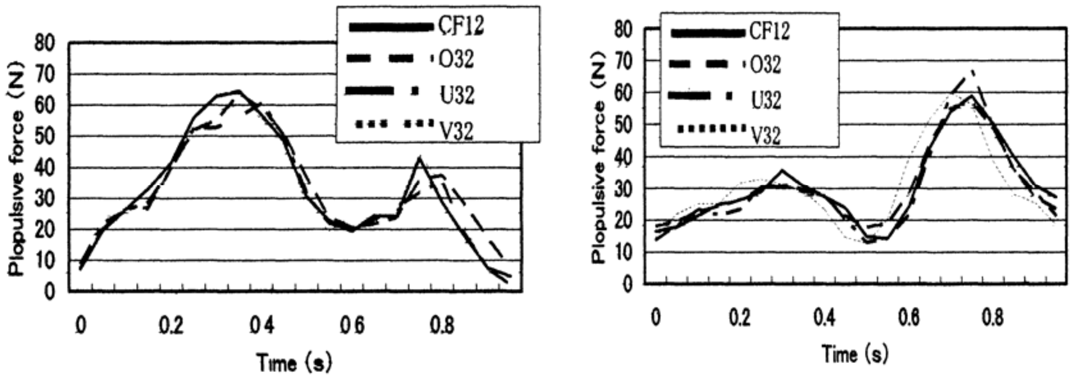


(a) Propulsive force at α＝0°　　　(b) Movement of monofin under one cycle

Figure 3. Propulsive force of α＝0° and configuration under one cycle of monofin

RELATIONSHIP BETWEEN PROPULSIVE FORCE AND WEARING ANGLE α＝−15°AND α＝+15°

The experiment which simulated the case in which it is swum by wearing the monofin in the ankle actually, was carried out. By wearing the monofin to the position of α=±5°、±10° and α=±20° from the level, the experiment measured the propulsion power which generated under up-kick and down-kick motion. Appearance of the propulsive force in case of α=-15° and α=+15° is shown in figure 4(a), (b).



(a) up-kick at α＝−15°　　　　　(b) down-kick at α＝＋15°

Figure 4. Propulsive force of wearing angle at α＝−15° and α＝＋15°

The propulsive force which generates under up-kick motion with the increase of α in minus direction from the level also increases. Also reversely, the propulsive force which generates under down-kick motion decreases. The wave form is different when comparing the change of the propulsive force of (a) and (b). In α=-15°, the propulsive force of up-kick increases most and down-kick decreases. In α=+15°, the propulsive force of down-kick decreases, and it increases the propulsive force in up-kick. Most propulsive force generates under up-kick motion.

RELATIONSHIP BETWEEN PROPULSIVE FORCE AND WEARING ANGLE α

Figure 5 shows the relation between the propulsive force and the wearing angle α. At α=0, the propulsive force which generates in up-kick and under down-kick is equal. The propulsive force under up-kick motion increases with the increase of α in minus side, but the propulsive force of down-kick motion becomes small. Reversely, the propulsive force under down-kick motion increases with the increase of α in plus side. The force which the monofin generates under feathering motion is divided into horizontal force and perpendicular force. The force which affects the propulsive force especially is the horizontal force. With the increase of α in minus side, the horizontal force which generates under up-kick motion increases, and the perpendicular force decreases. In the down-kick motion, the horizontal force decreases and the perpendicular force increases, as the result the propulsive force decreases. When α is plus, up-kick motion seemed to generates most propulsive force under down-kick motion, since this relation is reversed.

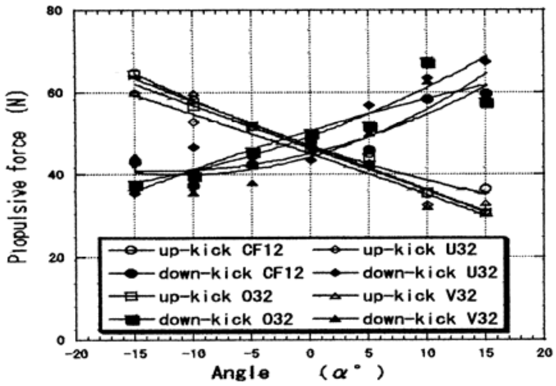


Figure 5. Relationship between propulsive force and wearing angle α

RELATIONSHIP BETWEEN IMPULSE AND WEARING ANGLE

The impulse for α from the propulsive force was obtained. The impulse is important in order to know the momentum for one cycle under up-kick and down-kick motion. The relationship between α and impulse is shown in Figure 6. The most impulse is at up-kick of α=－15°. The difference of impulse under up-kick and down-kick motion decreases with approaching α＝０°. The impulse becomes equal at α=5 °. In α=0°, value of the impulse in up-kick motion and down-kick does not become equal. This reason is because the deformation behavior of monofin under up-kick and down-kick motion differs, since the material of the monofin is elastic board.

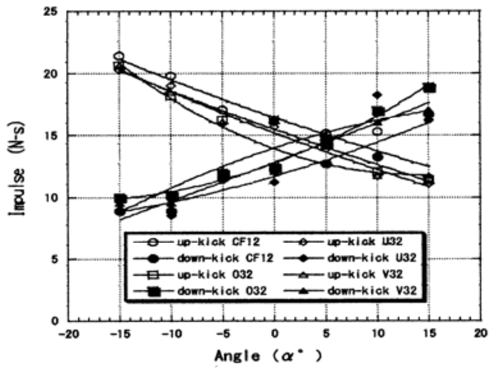


Figure 6. Relationship between impulse and wearing angle

CONCLUSION

The propulsive force which generated under feathering motion was measured on wearing angle and shape of the monofin. The followings were obtained

1. By measurement of the propulsive force under feathering motion of the monofin, we can evaluate the performance.
2. The difference of wearing angle of the monofin affects the propulsive force.
3. Most propulsive force generates up-under kick motion.

REFERRENCES

1. Hiroshi T., Youzi N., Takeo N., (2002) Motion analysis and shape evaluation of swimming monofin. The engineering sports 4. Blackwell Publishing. 716-724.
2. Hiroshi T., Youzi N., Takeo N., (1998) Study on measurement of water pressure during feathering motion of monofin. Test.*JSME, Symposium on Sports Engineering,* No.98-34. 231-235
3. Hiroshi T., Youzi N., Takeo N., (1997) Investigation on Estimation of Monofin by Measurement of Water Pressure. Test.*JSME, Symposium on Sports Engineering*, No.97-34, 130-133.

Assessment of Action in the Upper Part of the Body on Upwind Dinghy Sailing Performance using a Differential GPS

Koichi CHIASHI[1], Ko TAKAHASHI[2], Akira MAEDA[1]

[1] National Institute of Fitness and Sports (NIFS) in Kanoya,JAPAN

[2] Graduate School of Physical Education, NIFS in Kanoya,JAPAN

In competitive sailing where a race course is marked out by anchored floats on the sea surface, close-hauled, sailing, a technique for sailing upwind, accounts for about 60% of total race time. While sailing close-hauled, waves from the upwind direction cause the boat to slow down, and in order to minimize deceleration, the sailor leans the upper body backward. The present study investigated the effects on boat speed of the posterior leaning of the upper body while sailing close-hauled. Subjects were six male competitive sailors, and the study was conducted using an international Laser class single-person dinghy. The study was conducted in a hike out condition with wind speeds of 5-7 m/s with or without the upper body leaning. Boat speed was measured using D-GPS (20 Hz, Hemisphere), and a digital camera was used to capture the movements of the sailor in the dinghy. In data analysis, an average speed per two-minute period was used to calculate deceleration based on the maximum and minimum velocities while going over waves. The results showed no significant differences in average velocity with or without the upper body leaning while riding in the left or right side of the boat. However, for an expert sailor, the upper body leaning significantly increased boat velocity. No significant differences were seen in deceleration with respect to the upper body leaning. The results suggest that for top-level competitive sailors, the upper body leaning is important and is a factor that affects boat speed.

Key Words: *Upwind Dinghy Sailing, D-GPS, Action in the Upper Part of the Body*

INTRODUCTION

In competitive sailing (yachting), close-hauled sailing is a technique used to sail upwind, and it is possible to sail upwind by repeating close-hauled sailing and tacking (change of direction). In close-hauled sailing, the boat is subjected to waves while sailing upwind, and waves slow the boat down. Posterior leaning of the upper body (hereinafter referred to as body action) is a technique that minimizes boat deceleration by the sailor leaning the upper body backward while the boat hits a wave and is going over a wave. Investigating body action is important for improving the speed of close-hauled sailing. However, to the best of our knowledge, no study has scientifically analyzed the effects of body action in competitive sailing. The present study was conducted to ascertain the effects on boat speed of body action during close-hauled sailing.

Table1 Characteristics of study subjects

subject	Height (cm)	Weight (kg)	Age (years)
A	173	80	29
B	181	83	44
C	179	80	21
D	176	77	24
E	179	68	20
F	176	70	21
Ave.	177.3	76.3	26.5
S.D.	±2.9	±6.0	±9.2

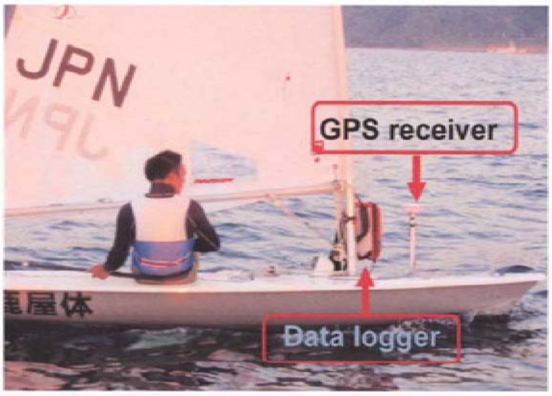


Figure1 A high-performance differential global position system (GPS) unit (Crescent A100, 20 Hz, Hemisphere) was placed in the bow of the boat to measure boat speed

METHODS

Subjects were six male competitive sailors (average height: 177.3±2.9 cm, average body weight: 76.3±6.0 kg, and average age: 26.5±9.2 years). The study was conducted using a single-person Laser class dinghy. The study was conducted in a hike-out condition with wind speeds of 5-7 m/s. Each sailor was instructed to sail close-hauled for 4 minutes. For the first 2 minutes, the sailor was instructed to sail with body action, and for the last 2 minutes, the sailor was instructed to sail without body action. Each sailor made two runs by riding the left and right sides of the boat. While sailing, the sailor was instructed to sail close-hauled as much as possible without using the rudder or main sheet. With body action, the sailor was instructed to lean the upper body backward once per wave, and without body action, the sailor was instructed to maintain normal sailing posture. A single set consisted of a 4-minute run on the left and right sides. Each sailor performed one set, except for Subject A, an expert competitive sailor, who sailed six sets. A high-performance differential global position system (GPS) unit (Crescent A100, 20 Hz, Hemisphere) was placed in the bow of the boat to measure boat speed. A camcorder (SONY) on a motorboat was used to capture the boat and sailor by following the boat on the side from the upwind direction. Wind direction and speed were measured before and after each run. Average speed and deceleration were calculated over each 2-minute period. The rate of deceleration was calculated by dividing the difference between maximum speed

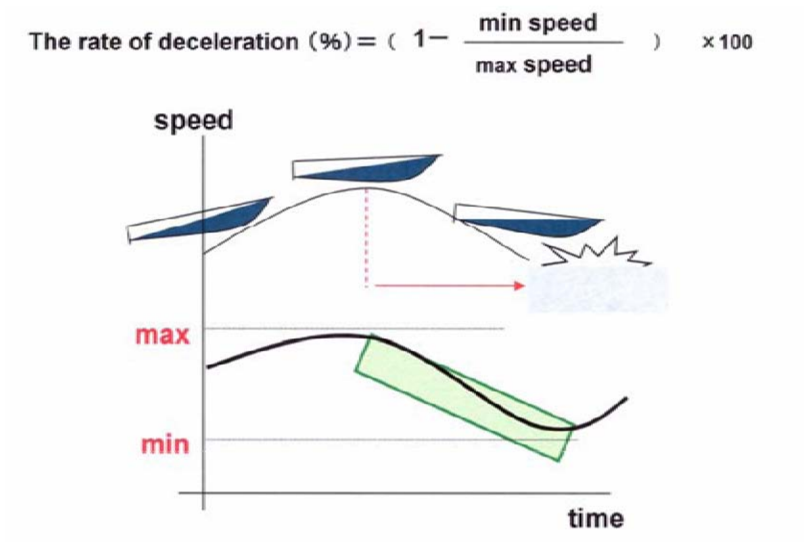


Figure2 The rate of deceleration was calculated by dividing the difference between maximum speed and minimum by the minimum speed while going over a wave

and minimum by the minimum speed while going over a wave. Averages were calculated for each condition. A paired t-test was used to compare averages within each subject, and one-way ANOVA was used to compare averages among the subjects. Significant F values were further subjected to a Bonferroni multiple comparison. Also, in all analyses, the level of significance was set at $p<0.05$, and SPSS 14.0J for Windows was used.

RESULTS and DISCUSSION

Figure 3 shows the average boat speed for all subjects. When riding the left side, the average velocity with body action was 2.38±0.15 m/s and without body action 2.29±0.14 m/s. When riding the right side, the average velocity with body action was 2.42±0.19 m/s and without body action 2.35±0.19 m/s. No significant differences existed in boat speed with or without body action when riding the left or right side.

However, for Subject A, when riding the left side, the average velocity with body action was 2.50±0.07 m/s and without the body action 2.39±0.1 m/s. When riding the right side, the average velocity with body action was 2.43±0.12 m/s and without the body action 2.34±0.11 m/s. Whether riding the left or right side, the average velocity was significantly faster with body action ($p<0.001$ and $p<0.01$, respectively).

The results suggest the efficacy of body action. However, the present study did not closely examine body action. In the future, the technical factors for body action must be closely examined. Also, no significant difference was found in overall average velocity, thus suggesting that body action is a technique with a high level of difficulty. The subjects other than Subject A had not mastered body action, and they might not have properly sailed close-hauled with body action.

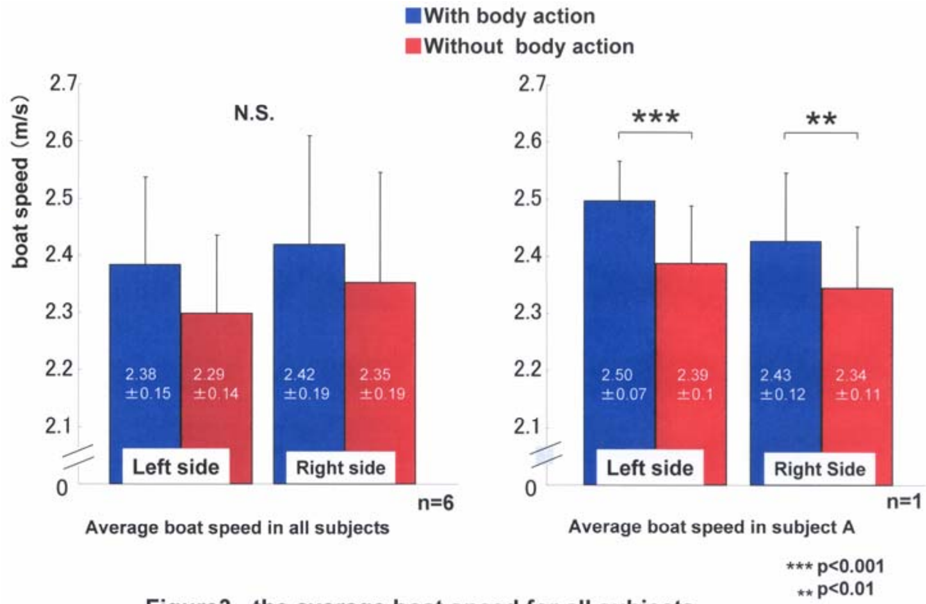


Figure3 the average boat speed for all subjects

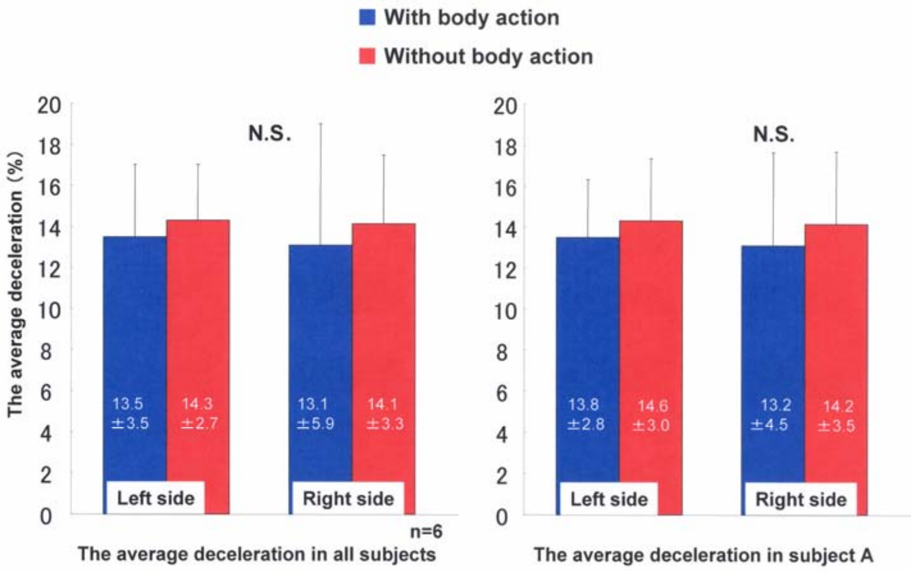


Figure4 The average deceleration for the six subjects and Subject A

Figure 4 shows the average deceleration for the six subjects and Subject A. For the six subjects, when riding the left side, the average deceleration with body action was 13.5±3.5% and without the body action 14.3±2.7%. When riding the right side, the average deceleration with body action was 13.1±5.9% and without body action 14.1±3.3%. No significant differences were found in boat speed with or without body action when riding the left or right side.

For Subject A, when riding the left side, the average deceleration with body action was 13.8±2.8% and without body action 14.6±3.0%. When riding the right side, the average deceleration with body action was 13.2±4.5% and without body action 14.2±3.5%. No significant differences existed in boat speed with or without body action when riding the left or right side.

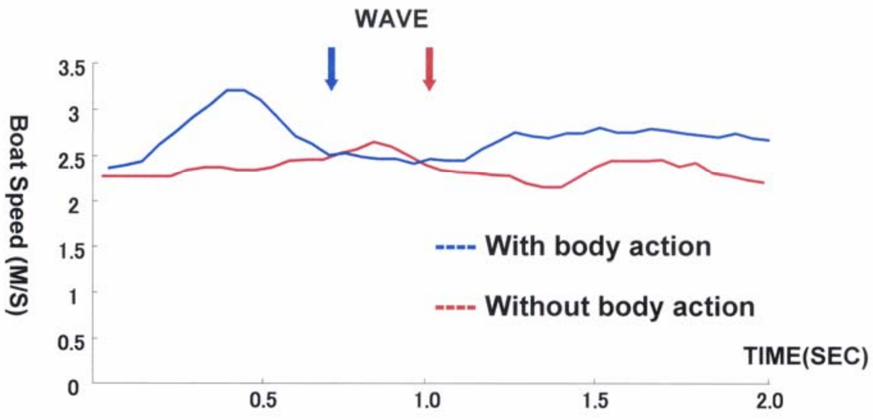


Figure5 Typical example of velocity changes over a 2-second period from when the boat is hit by a wave

In sailing, avoiding waves appears difficult. The types of resistance working on the boat include: (1) viscous friction, (2) viscous pressure, and (3) wave resistance. Viscous friction is unavoidable for boats, and viscous pressure can be minimized by making boats narrow. Wave resistance can be minimized by altering boat shape. Therefore, in the science of naval architecture, many studies have been conducted on the relationship between boat shape and waves. In this manner, the effects of waves can be minimized only by improving boat design.

In the present study, each wave decelerated the boat by about 15%. This information is interesting when considering the effects of waves on the deceleration of Laser class dinghies. The results suggest that the boat absolutely decelerates when hit by waves, and the impacts of waves cannot be sufficiently avoided by body action alone. Therefore, it appears important to control the boat to minimize the impacts of waves rather than to respond after being hit by waves.

Figure 5 shows a typical example of velocity changes over a 2-second period from when the boat is hit by a wave. The arrows in the figure indicate the time point when the boat collided with a wave. Based on the velocity changes, with or without the body action, velocity increased when the boat headed towards the wave peak. This phenomenon was seen when the boat collided with one well-defined wave. Our original assumption was that as the boat heads towards the peak, the boat decelerates as it climbs a slope. However, the data indicate the opposite. The reason for this phenomenon may be that as the boat comes into contact with a wave, lift is generated at the bottom of the boat.

CONCLUSIONS

The present study suggests the importance of body movements for top-level competitive sailors, and body action may be a factor determining boat speed. The present study is significant because the results suggest the possibility of body action being a factor for competitive sailing performance. Deceleration was measured to ascertain the effects of body action on single waves, but body action did not have marked impact on boat speed while going over individual waves. Also, a Laser class dinghy decelerated by about 15% when hit by a wave. Since avoiding waves is difficult, controlling the boat to minimize the impacts of waves seems important, rather than trying to deal with waves after being hit. In the future, the optimal extent and timing of body action must be closely investigated.

REFERENCES

1) Blackburn, M.：Physiological responses to 90 min of simulated dinghy sailing,J Sports Sci 12:383-390,1994

2) Bonjsen-Moller, J., B. Larsson, S. P. Magnusson, P. Aagaard : Yacht type and crew-specific differences in anthropometric, aerobic capacity, and muscle strength parameters among international Olympic class sailors, J. Sports Sci. 25(10):1117-1128,2007

3) Castagna, O., J. Brisswalter：Assessment of energy demand in Laser sailing : influences of exercise duration and performance level, Eur. J. Appl. Physiol. 99(2):95-101, 2006

4) Felici, F., A. Rodio, A. Madaffari, L. Ercolani, M. Marchetti：The Cardiovascular work of competitive dinghy sailing, J. Sports Phys. Fitness 39:309-314, 1999

5) Mackie, W. H., J. S.Legg：Preliminary Assessment of force demands in Laser racing,J. Sci. Med. Sport 2(1):78-85,1999

6) Putnam, C.A.：A mathematical model hiking positions in a sailing dinghy, Med. Sci. Sports 11(3):288-292, 1979

7) Sekulic, D., V. Medved, N. Rausavljevi, V, Medved：EMG analysis of muscle load during simulation of characteristic postures in dinghy sailing,J Sports Med Phys Fitness 46:20-27,2006

8) Shephard, R. J.：The biology and medicine of sailing, Sports Med. 9(2):86-99, 1990

9) Spurway, N.C., R. Burns：Comparison of dynamic and static fitness-training programmes for dinghy sailors－and some questions concerning the physiology of hiking, Med. Sci. Res. 21:865-867, 1993

10) Tan, B., A. R. Aziz, N. C. Spurway, C. Toh, H. Mackie, W. Xie, J. Wong, F. K. Fuss, K.C. The：Indicators of maximal hiking performance in Laser sailors, European Journal of Applied Physiology 98(2):169-176, 2006

11) Vogiatzis, I., C. N. Spurway, J. Wilson, C. Boreham：Assessment of aerobic and anaerobic demands of dinghy sailing at different wind velocities,J.Sports Med.Phys.Fitness 35:103-107,1995

12) Vogiatzis, I., N.K. Roach, E.A. Trowbridge：Cardiovascular, muscular and blood lactate responses during dinghy ‘hiking’, Med. Sci. Res. 21:861-863, 1993

Acknowledgement. The present study was conducted with financial aid from the 2007 General (C) Grant-in-Aids for Scientific Research "Practical research for developing a coaching assistance system for competitive sailing (representative: Koichi Chiashi)".

How do synchronized swimmers keep their legs above the water surface?

Miwako Homma[1], Masanobu Homma[2], Kanako Washizu[3]

[1] University of Tsukuba, Institute of Health and Sport Sciences, Japan

[2] Kobe University, Faculty of Maritime Sciences, Japan

[3] Japan Swimming Federation, Synchronized Swimming Committee, Japan

The present study defines the support scull techniques required to maintain a stable and maximal body height above water. We analyzed support scull movements performed by 10 top-ranked synchronized swimmers of the world by employing the 3-D DLT technique. The support scull techniques that efficiently generated lift comprise a horizontal sculling motion from inside to outside during the out-scull, a smooth transition of the attack angle during sculling, and a large forearm supination angle during the stroke phases to ensure that the palms face downwards. When swimmers lifted both legs, larger upper arm motion ranges and higher sculling tempo were required to maintain the maximal height above the surface of the water. In the crane position, swimmers maintained body balance by holding their right arms close to the body and by maintaining a small left wrist flexion throughout sculling.

Key words: *support scull, synchronized swimming, vertical position, crane position*

Introduction

In synchronized swimming, while performing both routines and figures, the vertical and crane positions are frequently used as the basic positions. The support scull is used in the vertical and crane positions as a propulsive and support technique, wherein the body must be maintained stably and as high as possible above water. Homma (4) reported that the load above the water surface at the maximal height were 14.8 and 6.6 kgf in the vertical and crane positions respectively, which meant that a double leg lift had to support a load 2.2 times the load supported in a single leg lift. Hall (3) also suggested that in the vertical position, the support scull had to generate a force capable of supporting approximately double the weight in the crane position. This generation of extra force is because the wrist motion is much larger in the vertical position and the stroke cycle time is shorter when both the legs are lifted. Since swimmers generate much larger propulsive forces in the vertical position than in the crane position, it is

apparent that support scull techniques in the vertical and crane positions are different.
Although support sculling is a necessary skill in synchronized swimming, few studies have investigated this technique (1,3,5,6). These studies, however, merely compared the movements of the less skilled swimmers with those of the more experienced swimmers; in addition, they analyzed sculling two-dimensionally, although it is a three-dimensional movement. Only two studies (3,5) have analyzed the support scull using the 3-D DLT method.
The present study analyzes the support scull movements performed by the world top-ranked synchronized swimmers by employing the 3-D DLT method of analysis; it attempts to define support scull techniques in the vertical position and obtain kinematical differences between the support scull techniques in the vertical and crane positions.

Methods

Ten female synchronized swimmers provided written informed consent to participate in this study. Among these, 2 were silver medallists at the 2004 Athens Olympics, the 2005 World Championships and the 2006 World Cup. The swimmers maintained the stationary vertical and crane positions using support sculling with maximal effort (Figure 1). In this experiment, all the swimmers lifted their left leg upwards and extended their right leg forward. Two cameras were synchronized using a frame counter and an external signal that was generated by the synchronizing device. The videotapes were manually digitized using Frame DIAS II (DKH Co., Japan). Three-dimensional coordinates were obtained using a 3-D DLT method. Since the support scull involves repetitive movements, a single stable cycle was investigated by analyzing the arms of a swimmer during the performance of one cycle of the support scull. The stroke motion from the inside to outside was termed the ‘out-scull’, and the opposite motion was termed the ‘in-scull’. The point where the motion changed from the outside to inside was termed the ‘transition phase’. The kinematical variables for analysis were; trochanter major height, upper arm angles, elbow angles, scull range, angles of wrist flexion and extension and ulnar and radial deviation, forearm supination angles, scull cycle time, scull pattern, scull plane angles: the angles between the water surface and the planes drawn by the wrists.

Figure 1. Vertical (left photo) and crane (right photo) positions using support scull.

Table 1. Results of kinematical analysis during one support scull cycle in the vertical and crane positions for all swimmers (n = 10)

		Vertical position	Crane position (Left leg lifted)		
		Mean(L,R)	Mean(L,R)	Left	Right
Trochanter major height (m)		–0.24 ± 0.02	–0.10 ± 0.01 ***	–0.10 ± 0.01 ^	–0.11 ± 0.01
Upper arm angle (°)	*max*	42 ± 4	38 ± 4 *	43 ± 4 ^	34 ± 8
	min	11 ± 2	16 ± 7 *	20 ± 12	12 ± 3
	range	31 ± 5	23 ± 10 *	23 ± 11	22 ± 9
Elbow angle (°)	*max*	147 ± 7	146 ± 7	150 ± 7 ^^	142 ± 8
	min	116 ± 8	117 ± 8	119 ± 10	116 ± 8
	range	30 ± 9	29 ± 6	32 ± 6	26 ± 9
Scull range (°)	*max*	82 ± 8	78 ± 6	78 ± 6	77 ± 10
	min	–20 ± 4	–21 ± 4	–21 ± 6	–21 ± 8
	range	102 ± 8	99 ± 7	99 ± 9	98 ± 8
Wrist flexion(+) extension(−) angle (°)	*flexion peak*	2 ± 6	0 ± 5	-3 ± 5 ^^	3 ± 7
	extension peak	–26 ± 6	–26 ± 7	–26 ± 10	–27 ± 6
	range	28 ± 6	27 ± 6	23 ± 9	30 ± 7
Wrist ulnar(+) radial(−) deviation angle (°)	*ulnar peak*	28 ± 6	28 ± 7	24 ± 9	32 ± 9
	radial peak	–15 ± 3	–15 ± 5	–15 ± 5	–15 ± 5
	range	43 ± 6	41 ± 7	39 ± 10	43 ± 7
Forearm supination angle (°)	*out-scull peak*	132 ± 8	132 ± 9	129 ± 11	134 ± 9
	in-scull peak	22 ± 12	27 ± 10	22 ± 10 ^	31 ± 12
	range	110 ± 16	105 ± 13	107 ± 16	103 ± 12
Scull cycle time (s)		0.65 ± 0.03	0.67 ± 0.05	0.67 ± 0.05	0.67 ± 0.05

The values for all the swimmers have been presented as mean ± standard deviation. L: left, R: right
max: maximal angle, min: minimal angle, range: difference between maximal and minimal angles

*** p < 0.001 , * p < 0.05 Significant difference between Vertical and Crane positions
^^ p < 0.01, ^ p < 0.05 Significant difference between Left and Right in Crane position

Results and Discussion

Table 1 shows the results of kinematical analysis during one support scull cycle in the vertical and crane positions for all the swimmers (n = 10). Since there were no significant differences between the left and right values in the vertical position, they were tabulated separately only for the crane position in Table 1.

Support Scull Techniques in Vertical Position

The front view of scull patterns revealed an ellipse sharply pointed on the inside or the larger out circle of a figure eight traced sideways (Figure 2). The hands of the skilful swimmers changed direction quickly at the inside transition phases, and the forearms moved outward from the inside with a horizontal orientation during the out-scull motion. This observation is in accordance with the findings of Hall (3), who analyzed support scull movements of three synchronized swimmers (gold medallists in the 1996 Atlanta Olympics) in the crane and vertical positions by employing a 3-D technique. The results of the study showed that the most skilful athlete maintained a small angle between the forearm and the horizontal surface. Moreover, Hall (2) provided a theoretical explanation for sculling and practical suggestions for the maximal use of lift force that can achieve efficient movement and position stability. Hall (2) suggested that the hands should always maintain an ideal foil angle and that horizontal sculling is important because the direction of the lift force is perpendicular to the sculling plane. On the other hand, Ito (6) has suggested that the sculling plane should be slightly inclined to the horizontal line in order to maintain position stability; this is because the lateral forces generated by the left and right arms are antagonistic. The scull plane angles obtained from the present study revealed that the swimmers maintained a slight incline. Consequently, sculling orientation, especially at the start of the out-scull, should be horizontal to produce the most efficient propulsive force. The

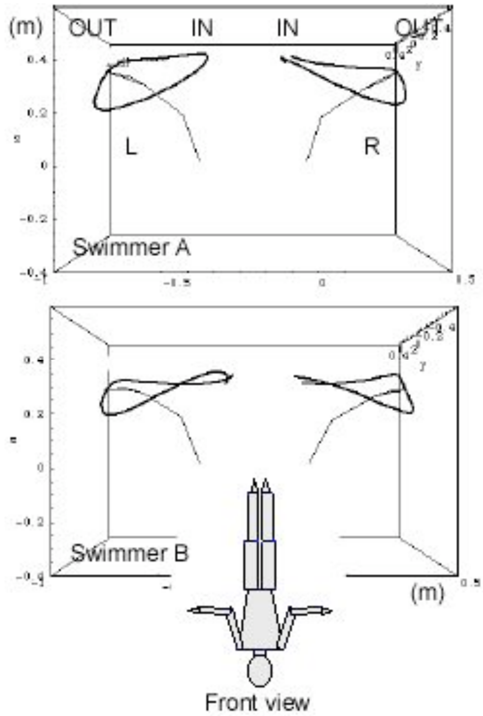


Figure 2. Front views of scull patterns of left and right hands during one support scull cycle performed by Japanese National Team Swimmers.

swimmers maintained a large forearm supination angle while sculling, as indicated by the palms facing the bottom of the pool throughout the movement. Such supination generates the optimal attack angle of the hand.

Skilful swimmers also had large scull ranges over 100º and the hands moved from the front of the center of the body to straight out to the sides so as to trace a quarter circle. These findings were consistent with those of Homma and Homma (5). When swimmers with an average body weight of 52.0 kg maintain a vertical position at 0.17 m above the kneecap, a 9.1 ± 0.6 kgf vertical force is exerted (4). In the present study, the 10 swimmers weighed an average of 52.0 kg, indicating that they maintained 9.1 kgf using only support scull movements. In order to maintain a greater height of the body above the water, maximal propulsive force needs to be generated; this is achieved by more vigorous sculling towards the bottom in the outside transition phase over a long sculling cycle. However, the propulsive force generated by sculling movements during synchronized swimming remains to be estimated in future studies.

Comparison of Support Scull Techniques between Vertical and Crane positions

The difference between the vertical and crane positions was exhibited only in the upper arm angles. The right maximal and left motion ranges of the upper arm angles were observed to be smaller in the crane position since the swimmers held their right arms close to the body and moved both their arms with small upper arm motion ranges. This result agrees with that obtained by Homma and Homma (5), in which the range of upper arm angles was larger under load. According to Hall (3), while lifting both legs, the swimmers increased the sculling speed for greater propulsion and moved their wrists in a larger trajectory. The results of a shorter sculling time under loads are consistent with Hall's finding, whereas the results of wrist motion are inconsistent with Hall's observation.

With respect to the left and right sides, there were no significant differences in the vertical position, but were some differences in the crane position. In the latter, the right maximal upper arm angles were smaller, the right maximal forearm supination angles at the in-scull were larger and the left wrist flexion motions were smaller. In the crane position, with the left leg lifted and right leg extended forward, it is conjectured that the center of gravity of the swimmers shifted slightly to the left side, in front of the body. The swimmers maintained their body balance by holding their right arms close to the body and maintaining a small left wrist flexion.

Conclusions

Kinematical analyses indicated that support sculling produces a propulsive force by generating greater drag during the outside transition phases and greater lift during the horizontal stroke phases of both in- and out-sculls. Support sculling, horizontal sculling orientation outward from the inside during the out-scull, and a large forearm supination during the stroke phases so as to keep the hands facing the bottom are important to efficiently generate lift. Moreover, when swimmers lift both their legs, larger upper arm motion ranges and higher sculling tempo are required to maintain the highest possible vertical position above the surface of the water. In the crane position, swimmers maintained their body balance by holding their right arms close to the body and maintaining a small left wrist flexion throughout sculling.

References

1. Francis PR and Smith KW (1982). A preliminary investigation of the support scull in synchronized swimming using a video motion analysis system. In Proceedings of the International Symposium of Biomechanics in Sports, Del Mar: Research Centre for Sports, Academic Publishers, 401-407.
2. Hall B (1985). The Mechanics of Sculling. Synchro, XXIII(5): 14-17.
3. Hall SJ (1996). Support scull kinematics in elite synchronized swimmers. In: XIII International symposium for biomechanics in sport: proceedings. Thunder Bay: Lakehead University, 44-47.
4. Homma M (2000). Load above the water surface during the movements in synchronized swimming. Bulletin of Sport Methodology. University of Tsukuba, 16: 13-22.
5. Homma M and Homma M (2006). Support scull techniques of elite synchronized swimmers. In: Vilas-Boas JP, Alves F and Marques A (Eds.) Biomechanics and Medicine in Swimming, 6(2): 220-223.
6. Ito S (2005). Optimal palm form in synchronized swimming. Proceeding of IXth Conference of Japanese Society of Sciences in Swimming and Water Exercise. 90-93.
7. Rybuyakova T, Lesgaft PF and Pybyakova TV (1991). Analysis of the vertical sculling technique. SYNCHRO, XXIX(3):18-21.

Reduced muscle oxygenation in the lower extremity during underwater treadmill walking

Kazuki Esaki[1], Koichi Kaneda[2], Daisuke Sato[2], Hitoshi Wakabayashi[3], Tohru Takemasa[2], Takeo Nomura[2], Takafumi Hamaoka[4], Toshihito Katsumura[1]

[1] Tokyo Medical University, Japan

[2] University of Tsukuba, Japan

[3] Kyushu University, Japan

[4] National Institute of Fitness and Sports in Kanoya, Japan

The purpose of this study was to determine muscle oxygenation in the lower extremities during underwater walking. Eight healthy men performed treadmill walking test twice, once in water and once on land. Muscle EMG activity (m-EMG) was monitored in the vastus lateralis (VL) and the medial head of the gastrocnemius (MG). The muscle oxygenation ($O_{2\text{-NIRS}}$) level was continuously monitored in the VL and the MG using near-infrared spectroscopy. The m-EMG levels of the MG and VL during underwater walking were comparable with the m-EMG during land walking. The $O_{2\text{-NIRS}}$ level, especially in MG, during underwater walking showed a greater decrease than that of land walking. The results of this study indicate that the greater decrease in the $O_{2\text{-NIRS}}$ level would be due to reduced muscle perfusion resulting from the facilitated venous return to the central circulation during underwater walking.

Key words: *muscle oxygenation level, under-water walking, muscle EMG activity*

INTRODUCTION

Water exercise, which has several physical properties such as hydrostatic pressure, buoyancy, and temperature, is often used for health promotion and rehabilitation programs. These properties are known to modify several physiological responses, including the increase in venous return to the central circulation and the reduction in weight loading to the joints and the muscles. Central circulation and whole body metabolism adjustments, in particular, have been investigated using respiratory gas analysis and heart rate (HR) measurement. However, local muscle circulation and oxidative metabolism have never been investigated during underwater walking. The development of near infrared spectroscopy (NIRS), a noninvasive method for measuring tissue oxygenation (1, 3, 4, 7), makes it possible to examine local muscle oxygenation. To understand whole-body and local muscle circulation and metabolism during underwater walking, it is essential to compare cardiorespiratory and local muscle metabolic responses between underwater and land walking at a given workload. Therefore, the purpose of this study was to investigate cardiorespiratory response and muscle oxygenation in the lower extremities during underwater walking on a treadmill.

METHODS

Eight healthy men (age 25 ± 3 y.r., height 175 ± 4 cm, weight 69.6 ± 5.7 kg, BMI 23 ± 2, $\dot{V}O_2$max 56.7 ± 5.9 ml/kg/min) performed a treadmill walking test twice, once in water and once on land (Figure 1).

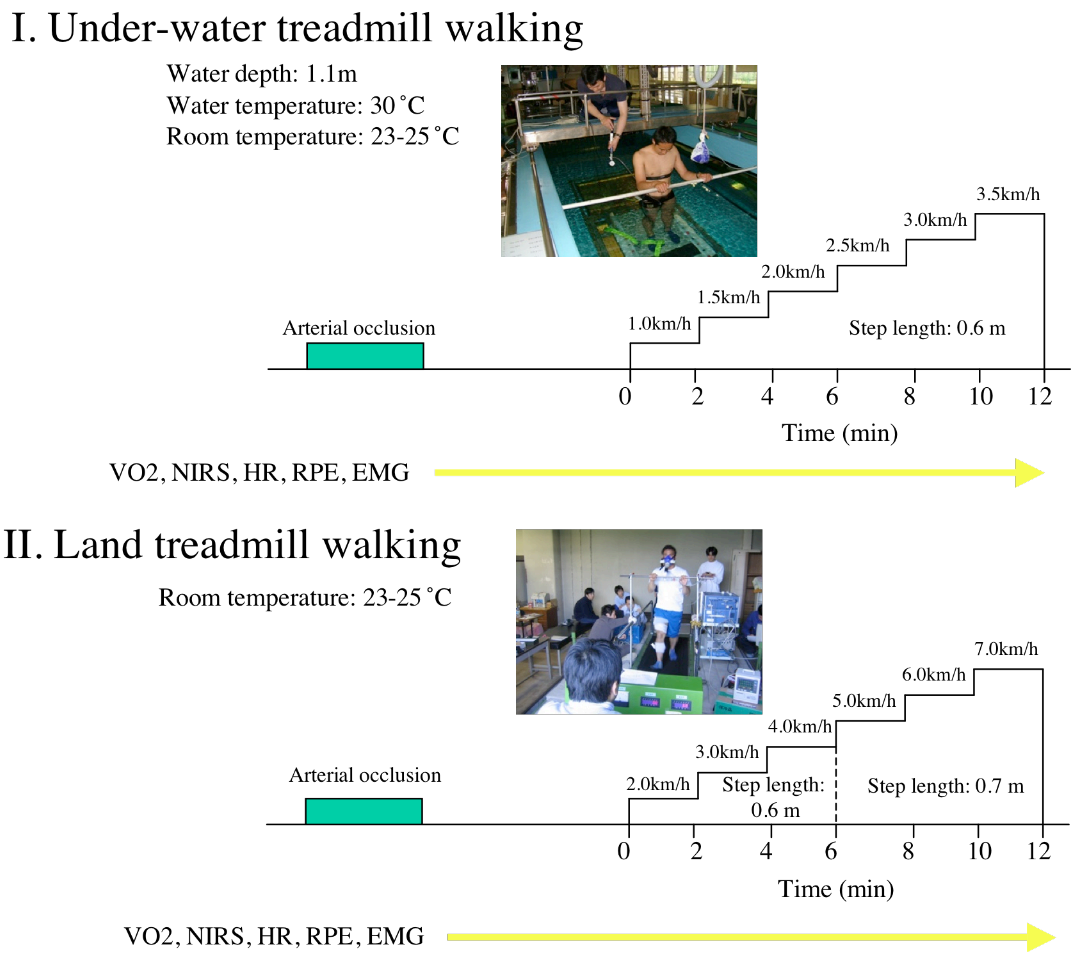


Figure 1 Protocol of underwater and land treadmill waking.

Informed consent was obtained for this experiment. Each subject began underwater treadmill walking at 1.0 km/h in 0.5 km/h increments until 3.5 km/h for 2 minutes each. To create the same level of physiological effort as underwater treadmill walking, approximately double the velocity has required for land treadmill walking (2). Each subject also began land treadmill walking at 2.0 km/h in 1.0 km/h increments until 7.0 km/h for 2 minutes each. The water temperature was set at 30°C and the water depth was set at 1.1m throughout the experiment. The room temperature and relative humidity were 23-25°C and 50-60%, respectively. Pulmonary oxygen uptake ($\dot{V}O_2$) was determined every 30 seconds during the experiment by an automatic breath-by-breath gas-exchange measurement system (AE-280, Minato Medical Science Co., Ltd., Japan). The HR was continuously monitored by a telemeter (Polar accurexPlus, Polar Electro Co., Finland). Muscle electromyographic (m-EMG) activity was monitored in the vastus lateralis (VL) and the medial head of gastrocnemius (MG). A pair of surface EMG electrodes (5mm diameter) was placed on the muscle belly with an inter-electrode distance of 2.5cm. The Root Mean Square (RMS) of one cycle was calculated. All muscle RMS values were presented as percentages of maximum voluntary contraction (%MVC) in each muscle.

The muscle oxygenation ($O_{2\text{-NIRS}}$) level was continuously monitored in the VL and the MG using NIRS (Model HEO-200, OMRON Ltd. Inc., Japan). The $O_{2\text{-NIRS}}$ level was measured by NIRS which has a flexible probe consisting of two LEDS that emit at 760 nm or 840 nm. The detector was 3 cm from the radiation source. Changes in oxygenated Hb and Mb (HbO_2), deoxygenated Hb and Mb (Hb) and total Hb (T-Hb) were calculated by a formula that has been established in a previous study (6). The sampling frequency was set at 0.5 sec. Ten minutes before the start of exercise, a pneumatic cuff on the proximal part of the thigh was inflated over 300 mmHg to occlude arterial blood flow for about 7 min until a minimal level of muscle oxygenation was reached. The $O_{2\text{-NIRS}}$ level was defined as 0% at the lowest value during cuff ischemia and 100% at the peak value during recovery from cuff ischemia. Ratings of perceived exertion (RPE) were obtained at rest and during exercise using Borg's 15-point scale.

RESULTS

Figure 2 shows HR, %$\dot{V}O_2$max, and $O_{2\text{-NIRS}}$ level during underwater and treadmill walking on land. The HR during underwater walking at a given relative $\dot{V}O_2$max was significantly lower than during land walking. The $O_{2\text{-NIRS}}$ level, especially in the MG, during underwater walking at a given relative $\dot{V}O_2$max showed a greater decrease than that of land walking. The m-EMG activity levels of the MG and VL during underwater walking were comparable with the m-EMG activity during land walking.

The prevailing %$\dot{V}O_2$max during the underwater treadmill exercise increased from an initial 30% to 60%. Similarly, RPE increased from an initial 12 to 14 at the end of exercise.

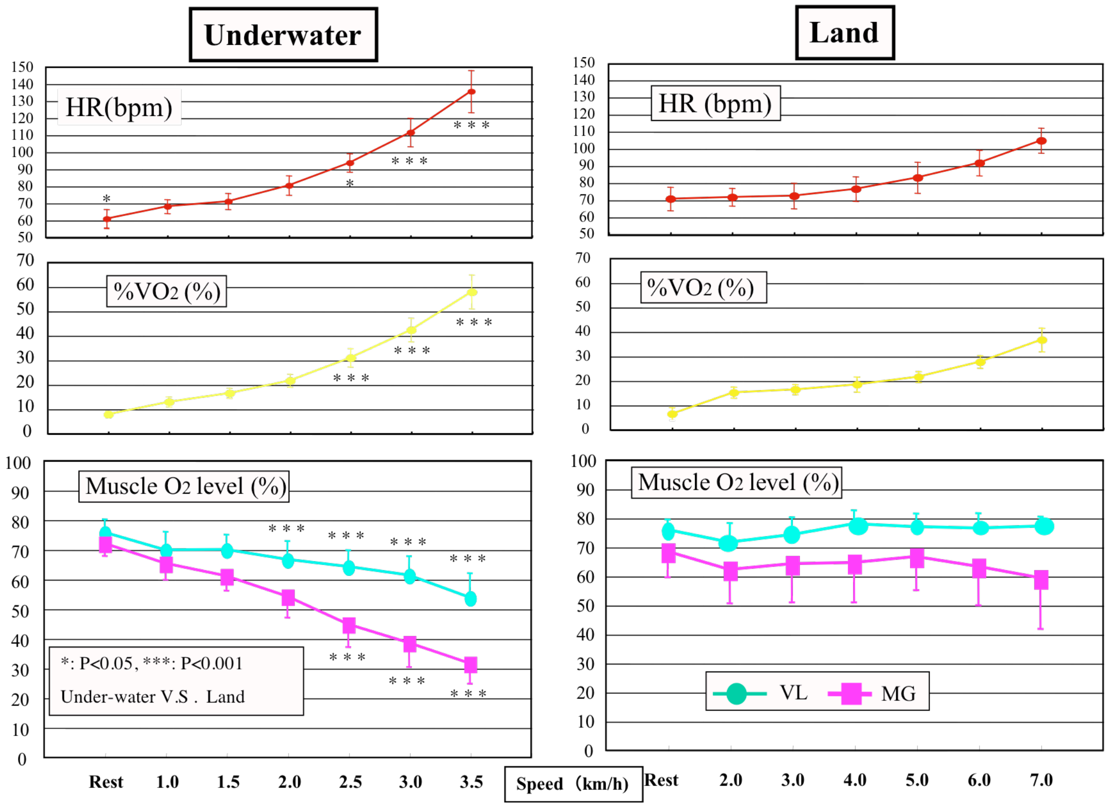


Figure. 2 Changes in HR, %$\dot{V}O_2$max, and $O_{2\text{-NIRS}}$ level during underwater and on-land treadmill walking.

DISCUSSION

In this study, resting HR was lower in water by approximately 10 bpm than on land. This result is due to the peripheral vasoconstriction resulting from increased hydrostatic pressure and the elevated stroke volume caused by increased venous return to the central circulation. To create comparable whole body oxygen consumption during exercise in water and on land, we set the walking speed to double for land walking (2). However, the HR and %$\dot{V}O_2$max were significantly greater during underwater walking than during land walking at higher walking speeds (2.5 km/h for on-land v.s. 5.0 km/h for underwater). The results of this study were inconsistent with those obtained by

Evans et al. (2). The difference was due to the mode of load having been exerted: a usual underwater walking for the study of Evans et al. (2) and an underwater treadmill walking for ours.

The m-EMG level was relatively larger in the GM during walking at a lower speed (1.0 km/h) than that in the VL. When increasing walking speed up to 3.5 km/h, the m-EMG levels in the VL started to increase. The result of this study was consistent with the data obtained by Kato et al. (5). The m-EMG levels of the MG and VL during underwater walking was comparable with the m-EMG levels during land walking. The results obtained using m-EMG suggested that muscle activation, an indirect indicator for muscle oxygen consumption, would be comparable both during exercises.

The $O_{2\text{-NIRS}}$ decreased greater in the MG than in the VL during both exercises. The results of this study were consistent with the data reported in a previous study (4) that had used an on land treadmill exercise. The $O_{2\text{-NIRS}}$ during underwater walking showed a greater decrease than during on land walking both in the MG and VL. The results obtained using NIRS suggest greater muscle oxygen consumption or reduced oxygen delivery to the muscle. The combination of EMG and NIRS results indicate that the greater decrease in the $O_{2\text{-NIRS}}$ level would be due to the reduced muscle perfusion resulting from the facilitated venous return to the central circulation during underwater walking.

CONCLUSION

The results of this study indicate that the greater decrease in the $O_{2\text{-NIRS}}$ level is due to reduced muscle perfusion resulting from the facilitated venous return to the central circulation during underwater walking. We believe that the results of this study provide useful information for prescribing underwater exercise programs for both healthy people and people suffering from disease.

Acknowledgements

This work was supported in part by Grants-in–Aid from the Mizuno Sports Foundations (2006) and by the twenty-first century COE (Center of Excellence) program, Ministry of Education, Culture, Sports, Science and Technology (2002-2006 Nishihira Project: Promotion of Health and Sport Scientific Research).

REFERENCES

1. Esaki K, Hamaoka T, Radegran G, Boushel R, Hansen J, Katsumura T, Haga S and Mizuno M. (2005). Association between regional quadriceps oxygenation and blood oxygen saturation during normoxic one-legged dynamic knee extension, Eur J Appl Physiol, 95: 361-70.
2. Evans BW, Cureton KJ, Purvis JW. (1978). Metabolic and circulatory responses to walking and jogging in water. Res Q., 49: 442-9.
3. Hamaoka T, Iwane H, Shimomitsu T, Katsumura T, Murase N, Nishio S, Osada T, Kurosawa Y and Chance B. (1996). Noninvasive measures of oxidative metabolism on working human muscles by near-infrared spectroscopy. J Appl Physiol, 81: 1410-7.
4. Hiroyuki H, Hamaoka T, Sako T, Nishio S, Kime R, Murakami M and Katsumura T. (2002). Oxygenation in vastus lateralis and lateral head of gastrocnemius during treadmill walking and running in humans. Eur J Appl Physiol, 87: 343-9.
5. Kato T, Sugagima Y, Koeda M, Fukuzawa S, Kitagawa K. (2002). Electromyogram activity of leg muscles during different types of underwater walking. Adv Exerc Sports Physiol, 8: 39-44.
6. Shiga T, Yamamoto K, Tanabe K, Nakase Y, Chance B. (1997). Study of an algorithm based on model experiments and diffusion theory for a portable tissue oximeter. J Biomed Opt 2: 154-161
7. Takemasa T, Miyakawa S, Nagata S, Esaki K, Hirokawa M, Machida M, Kosaka Y, Hitomi Y, Kizaki T, Ohno H, Haga S. (2004). Effect of hyperventilation during resistance exercise on hormonal response in humans. Adv Exerc Sports Physiol, 10: 55-61.

Concept Design of a Floating Biofeedback System for Mental Management and Health

Akira Shionoya[1], Masaaki Ohba[2], Toshinori Saijoh[1], Hidetoshi Saito[1] and Hitoshi Miyake[1]

[1] Nagaoka University of Technology

[2] Niigata University

Stress means the distortion of the physical or mental condition, which is caused by various stressors. Various countermeasures are needed against stress because the distortion of the physical or mental condition causes various physical and mental illnesses. The purpose of this study is to create the concept design of a floating biofeedback system for mental management and health. Supine floating was adopted as the floating method for the system. For the purpose of this study, the effect of supine floating on the autonomic nervous system was investigated experimentally. Subjects underwent 2 types of stress tests. After each stress test, subjects performed supine floating in a swimming pool. ECG data during the experiment was measured, transmitted to a computer, and transformed into a power spectrum by FFT. The concept design of a floating biofeedback system was created based on these experimental results.

Key words: *Stress, Floating, Biofeedback, Autonomic nerve system, ECG, FFT*

Introduction

Stress means the distortion of the physical or mental condition, which is caused by various stressors. Various countermeasures are needed against stress because the distortion of the physical or mental condition causes various physical and mental illnesses. The purpose of this study is to create the concept design of a floating biofeedback system for mental management and health.

Experiments

For the purpose of this study, the effect of supine floating on the autonomic nervous system was investigated experimentally. Subjects underwent 2 types of stress tests. One was an exercise stress test, the other was a mental stress test.

First, in the exercise stress test, the anaerobic threshold (AT) of each subject was measured using a bicycle ergometer. AT was determined based on the following standards: 1) the increase in VE, VCO_2, R; 2) the increase in the end tidal O_2 without increase in the end tidal CO_2; and, 3) the increase in VE/VO_2 without increase in VE/VCO_2. The exercise work load of the exercise stress test for each subject was determined based on this AT.

In the mental stress test, subjects were given the task of transferring a small plastic ball between 2 dishes using a pair of chopsticks. The diameter of the ball was 6 mm. The length between the 2 dishes was 30 cm. The chopsticks were made of wood.

The flowchart of both stress tests was as follows: 1) three minutes of sitting rest; 2) six minutes of each stress test; and, 3) six minutes of recovery. The subjects were five male students(Average of age was 22.8 (SD=1.1), height was 169.2 cm (SD =4.6) and weight was 64.8 kg (SD=6.3)). Recovery was attempted in both supine floating and supine non-floating conditions (Fig.1) in water temperature 26℃ and ambient temperature 30℃. During stress tests, an ECG (Polymate AP1000) was attached to each subject. The ECG data was transmitted to a personal computer, and the R wave interval (R-R interval) of the ECG was detected. Furthermore, R-R interval was transformed into a power spectrum using fast fourier transform (FFT) programming in the PC. The high frequency (HF: 0.15-0.40 Hz) in the spectrum was adopted as the index of parasympathetic nerve system activity. The ratio of the low frequency (LF:0.04-0.15 Hz) and HF was adopted as the index of sympathetic nerve system activity (Fig.2).

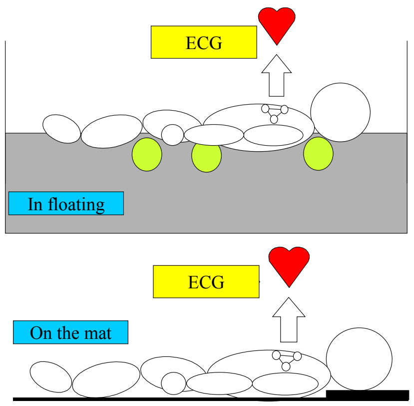


Figure 1: 2 recovery methods

in the stress test

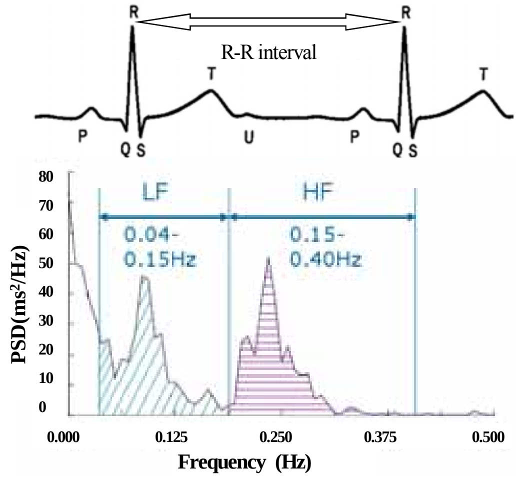


Figure 2: R-R interval and its frequency

Results and Additional Experiment for the Concept Design of the System

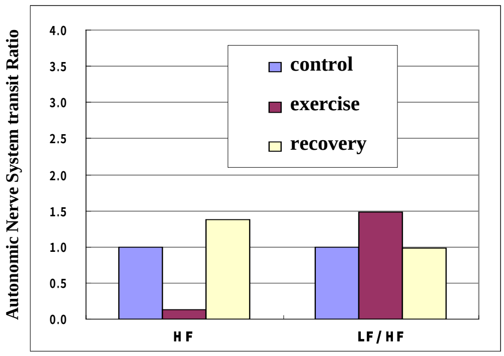
Fig.3 shows the results of the two stress tests. In the recovery phase, HF increased and LF/HF decreased in the floating condition as compared to the non-floating condition in both stress tests. As mentioned-above, HF was the index of the parasympathetic nerve system activity and LF/HF was the index of the sympathetic nerve activity. In these results, the positive effect of supine floating on the autonomic nerve system can clearly be seen.

To create the concept design of a floating biofeedback system, an additional experiment was done to better understand the reason why HF increased and LF/HF decreased in the floating condition in the recovery phase. Fig. 4 shows an outline of the additional experiment. After subjects to whom an ECG was attached performed the task of transferring a small plastic ball as the mental stress test, they recovered on a hammock under the following two conditions: 1) with the balance balls placed under the hammock; 2) without the balance balls placed under the hammock.

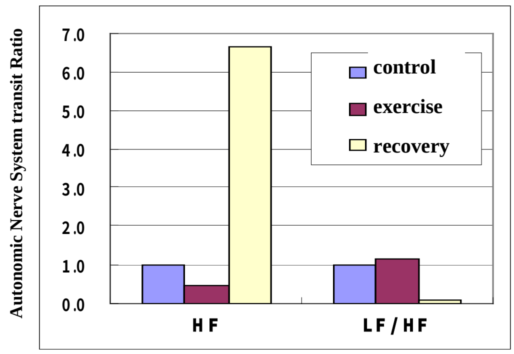
In this additional experiment, balance balls simulated the buoyancy in floating. The mathematical parameters of the buoyancy in floating are as follows:

$$F = -\rho V g, \quad \rho V g = mg$$

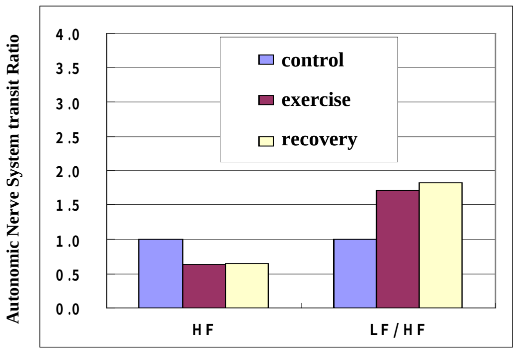
where、F：buoyancy [N]、ρ：density of water [kg/cm^3]、V：mass of the body weight under the water [m^3]、g：gravity [m/s^2] . That is; the buoyancy in floating is equal to the gravity. Fig.5 shows the results of the additional experiment. In the recovery phase, HF increased and LF/HF decreased when the balance balls were placed under the hammock as compared to not placing them under the hammock. According to these results, it would appear that the positive effect of supine floating on the autonomic nerve system was caused by buoyancy.



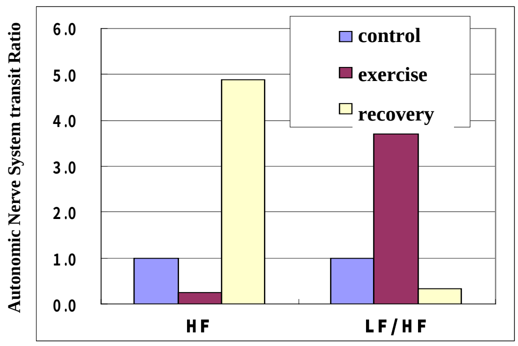
Non-floating recovery in exercise stress



Floating recovery in exercise stress



Non-floating recovery from mental stress



Floating recovery from mental stress

Figure 3 : HF and LF/HF changes in each stress test

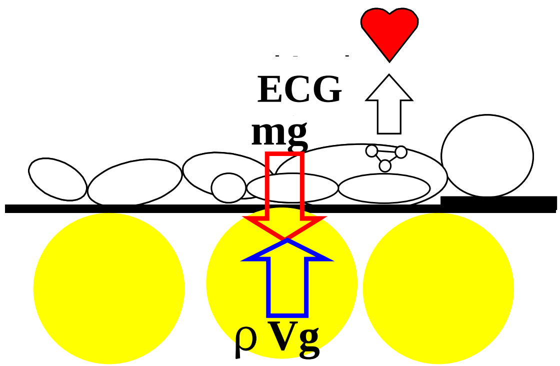
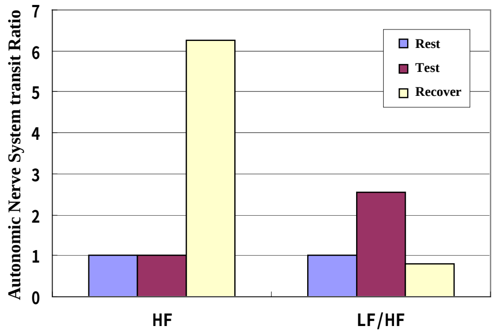
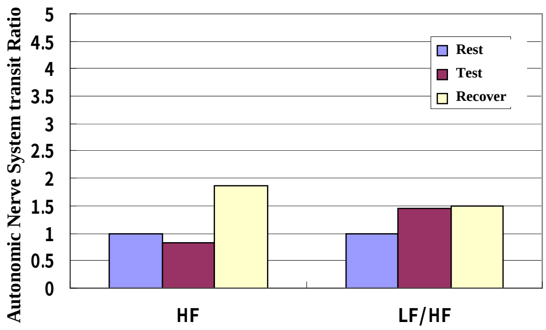


Figure 4: Outline of the additional experiment using a hammock



Placing the balance balls



Not placing the balance balls

Figure 5: HF and LF/HF changes in the additional experiment

Concept Design of the Floating Biofeedback System

Fig.6 shows the concept design of the floating biofeedback system. The polyurethane poles, which support supine floating, are connected to digital force gauges (IMADA DPX-50T; 490Nmax) and accelerometers (PIEZOTRONICS) through a wire. As mentioned above, the positive effect of supine floating on the autonomic nerve system appears to be caused by buoyancy. Using this system, a mechanical condition like buoyancy in floating can be synchronized with a physiological condition such as autonomic nervous system activity. Furthermore, the optimal condition of buoyancy for a positive effect on the autonomic nerve system can be achieved using this proposed system.

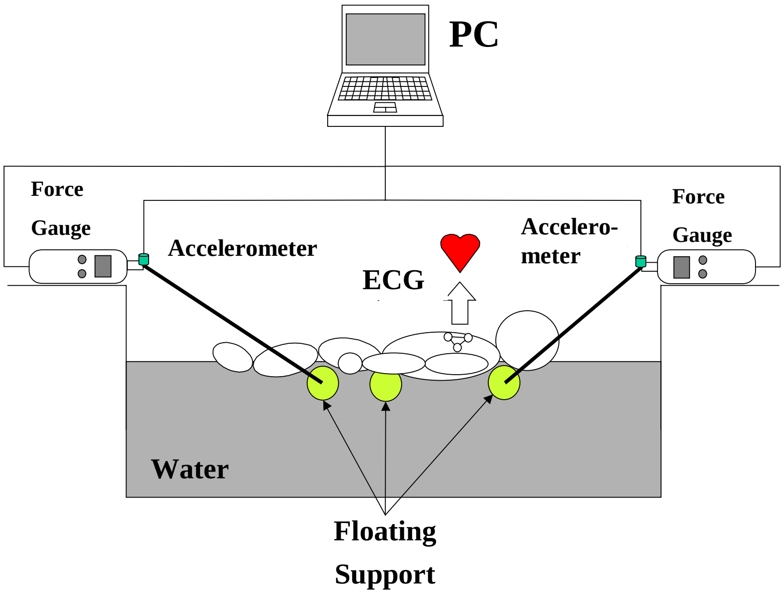


Figure 6: Concept design of a floating biofeedback system

References

1. Shionoya A, Ohba M, Miyake H. (2005). Force measurement in tethered swimming and power measurement in semi-tethered swimming. The impact technology on sport. 1: 367-372.
2. Shionoya A, Ohba M, Saijo T. (2007). Force measurement in tethered swimming and power measurement in semi-tethered swimming; force and power optimizations from physical elements. Asia-Pacific Conference on Exercise and Sport Science (Hiroshima University).

Acknowledgement

This study is supported by KOZUKI FOUNDATION.

Effects of immersion in different water temperatures before exercise on heart rate, cardiac parasympathetic nervous system activity and rectal temperature

Kazuki Nishimura[1], Asana Miyanishi[2], Mayo Komiyama[3], Akira Yoshioka[1], Kazutoshi Seki[1], Kumiko Ono[1], Sho Onodera[2]

[1]Graduate School, Kawasaki University of Medical Welfare, Health Science, Japan

[2]Kawasaki University of Medical Welfare, Health and Sports Science, Japan

[3]Graduate School, Kawasaki University of Medical Welfare, Health and Sports Science, Japan

The purpose of this study was to determine the effects of immersion in different water temperatures before exercise during exercise and post exercise. Eight healthy males volunteered for this study. Subjects performed arm crank exercise for 5 minutes after immersion for 15 minutes. Subjects maintained their supine position on land for 15 minutes after exercise. Experimental conditions were the control condition, the WT-25 and the WT-40. Exercise intensity was 50% peak $\dot{V}O_2$. Measurement items were heart rate, the cardiac autonomic nervous system activity (MemCalc) and rectal temperature. Heart rate and rectal temperature were significantly increased under the WT-40, compared to the C-condition and the WT-25 ($p < 0.05$). Log HF was significantly reduced under the WT-40, compared to the C-condition and WT-25 ($p < 0.05$). These data suggest that there are significant differences during exercise and post exercise to immersion in different water temperatures before exercise.

Key words: *immersion before exercise, cardiac parasympathetic nervous system activity, different water temperatures, arm-crank exercise, post exercise*

INTRODUCTION

In the water, humans have different physical responses compared to land due to influences of physical characteristics of water such as water temperature, water pressure, buoyancy and viscosity. Nishimura and Onodera[4)] (2000) reported on the relaxation effects of supine floating on heart rate, blood pressures and the cardiac autonomic nervous system activity, and suggested that the cardiac parasympathetic nervous system activity was significantly increased by supine floating. Nishimura et al.,[2] (2006) reported on the effects of the supine floating on rectal temperature and cardiac parasympathetic nervous system activity after high and moderate intensity exercise with a cycle ergometer, and suggested that supine floating after high and moderate intensity exercise with a cycle ergometer could promote the recovery of rectal temperature and increased the activity of cardiac parasympathetic nervous system which was inhabited by exercise. These studies suggested that influences of physical characteristics of water were significantly differences not only at rest but alsoa during recovery after exercise. Also, the increase in cardiac parasympathetic nervous system activity by supine floating continues for recovery on land (Nishimura et al.,[3] 2006). However, it doesn't make clear the effects of immersion before exercise during exercise and post exercise. Therefore, the purpose of this study was to determine the effects of immersion in different water temperatures before exercise on heart rate, the cardiac parasympathetic nervous system activity and rectal temperature during exercise and post exercise.

METHODS

Eight healthy males volunteered for this study. Their mean age, height, weight and % body fat were 21.6±1.4years (mean±SD), 172.1±6.1cm, 68.1±8.3kg, 18.0±5.2%, respectively. All subjects signed an informed consent form prior to participation in this study. Subjects performed arm crank exercise for 5 minutes after immersion for 15 minutes. Subjects maintained their supine position for 10 minutes. Experimental conditions were three conditions: The control condition (C-condition) sitting position on land, WT-25 (water temperature was 25 degrees Celsius) and the WT-40 (water temperature was 40 degrees Celsius). Exercise intensity was 50% peak $\dot{V}O_2$. Measurement items were heart rate, the cardiac autonomic nervous system activity and rectal temperature. The cardiac autonomic nervous system activity was calculated using Maximum entropy methodology calculation (MemCalc). The frequency domain was divided into two parts: high frequency (HF; 0.15-0.40Hz) and low frequency (LF; 0.04-0.15Hz). The cardiac autonomic nervous system activity was transformed into logarithmic values to obtain a statistically normal distribution. Log HF was an index of the cardiac parasympathetic nervous system activity. Room temperature and humidity were 24.5±1.3 degrees Celsius and 70.6±6.3%, respectively. All experiments were performed at the same hour in each morning (9-12 a.m.). All subjects ate nothing after 10 p.m. prior to the experiment day till the next morning. Also, caffeine components were not allowed for three hours before experiment. All data were expressed as mean±SD. Two-way analysis of variance for repeated measurements was used for comparison of each measured value among conditions. The level of significance was set up as $p < 0.05$.

RESULTS

All measurement items of rest on land showed no significant difference under three experimental conditions. Figure 1 shows changes in heart rate during the experimental period. During immersion, heart rate was significantly increased under the WT-40, compared to the C-condition and the WT-25 ($p < 0.05$). During exercise and post exercise, heart rate was significantly increased under the WT-40, compared to the C-condition and the WT-25 ($p < 0.05$). Figure 2 shows changes in log HF during the experimental period.

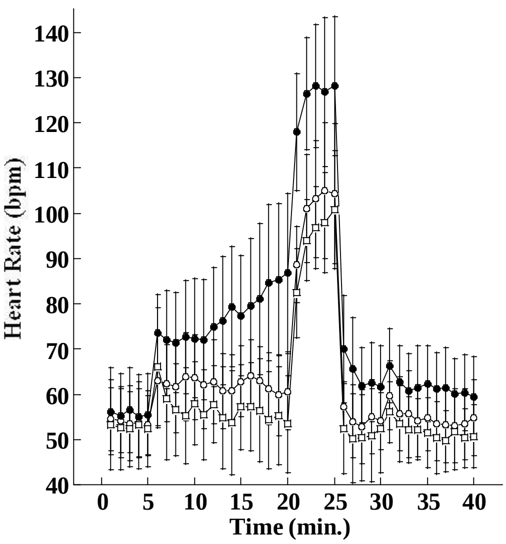


Figure 1. Changes in heart rate under three experimental conditions (show the explanatory notes).
●: WT-40, □: WT-25, ○: C-condition.
ANOVA; $p < 0.05$, WT-40 vs. C-condition, WT-40 vs. WT-25

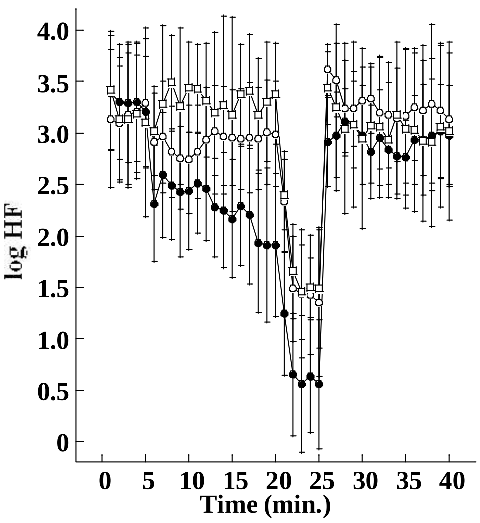


Figure 2. Changes in log HF under three experimental conditions (show the explanatory notes).
●: WT-40, □: WT-25, ○: C-condition.
ANOVA; $p < 0.05$, WT-40 vs. C-condition, WT-40 vs. WT-25

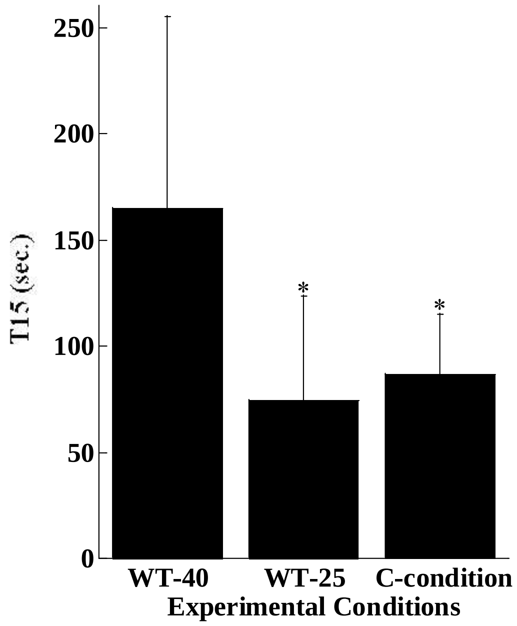


Figure 3. Changes in T15 under three experimental conditions (show the explanatory notes).

*; p< 0.05, WT-40 vs. C-condition, WT-40 vs. WT-25

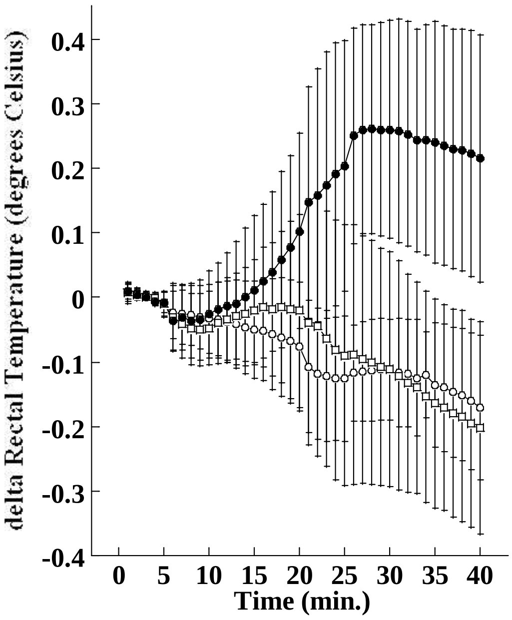


Figure 4. Changes in rectal temperature under three experimental conditions (show the explanatory notes).

●: WT-40, □: WT-25, ○: C-condition.

ANOVA; p< 0.05, WT-40 vs. C-condition, WT-40 vs. WT-25

During immersion, log HF was significantly reduced under the WT-40, compared to the C-condition and the WT-25 ($p < 0.05$). During exercise, log HF was significantly reduced under the WT-40, compared to the C-condition and the WT-25 ($p < 0.05$). During post exercise, log HF showed no significant difference under these conditions. Figure 3 shows change in the time constants of the beat-by-beat heart rate decay for the first 15 seconds after exercise (T15). T15 in the WT-40 after exercise was significantly higher than C-condition and WT-25 ($p < 0.05$). Figure 4 shows change in rectal temperature during the experimental period. Point 0-0 is rest on land. During immersion, delta rectal temperature was significantly increased under the WT-40, compared to the C-condition and the WT-25 ($p < 0.05$). During exercise and post exercise, delta rectal temperature was significantly increased under the WT-40, compared to the C-condition and the WT-25 ($p < 0.05$).

DISCUSSION

During immersion, heart rate was significantly increased under the WT-40, compared to the C-condition and the WT-25 ($p < 0.05$). And, log HF was significantly reduced under the WT-40, compared to the C-condition and the WT-25 ($p < 0.05$). Matsui et al.,[1] (2005) suggested that stroke volume, heart rate and cardiac output were significantly increased, and log HF was significantly reduced during immersion in 41 degrees Celsius. This study showed similar tendency. The increased heart rate and reduced in log HF caused by effects of hyperthermia. Delta rectal temperature was significantly increased under the WT-40, compared to the C-condition and the WT-25 ($p < 0.05$). The conductive heat transfer coefficient of water is 25 times higher than that of air. This means that venous return was warmed during immersion in WT-40. During exercise and post exercise, heart rate was significantly increased under the WT-40, compared to the C-condition and the WT-25 ($p < 0.05$). And, delta rectal temperature was significantly increased under the WT-40, compared to the C-condition and the WT-25 ($p < 0.05$). During exercise, log HF was significantly reduced under the WT-40, compared to the C-condition and the WT-25 ($p < 0.05$). T15 in the WT-40 after exercise was significantly higher than the C-condition and the WT-25. These results mean that effects of immersion in WT-40 continue for next exercise and post exercise.

CONCLUSION

These data suggest that there are significant differences on heart rate, the cardiac parasympathetic nervous system activity and rectal temperature during exercise and post exercise to immersion in different water temperatures before exercise.

REFERENCES

1. Takeshi Matsui, Motohiko Miyachi, Linda Massako Ueno and Sho Onodera (2005) Effects of Bathing and Post-exercise on Autonomic Cardiovascular Regulation in Middle-aged and Other man. Desecente Sports Science, 25, 145-157.

2. Kazuki Nishimura, Kazutoshi Seki, Kumiko Ono and Sho Onodera (2006) Effects of the Supine Floating on Rectal Temperature and Cardiac Parasympathetic Nervous System Activity after Exercise with a Cycle Ergometer. Japanese Journal of Aerospace and Environmental Medicine. 43, 11-18.

3. Kazuki Nishimura, Kazutoshi Seki, Takeshi Okamoto, Daisuke Nishioka, Kumiko Ono and Sho Onodera (2006) Effects of the Supine Floating on Cardiac Autonomic Nervous System Activity after Treadmill Exercise in Water. Biomechanics and Medicine in Swimming X, 156-158.
4. Masahiro Nishimura and Sho Onodera (2000) Relaxative Effects of Supine Floating on Heart Rate, Blood Pressure and Cardiac Autonomic Nervous system Activity. Japanese Journal of Aerospace and Environmental Medicine. 37, 49-56.

Human thermal model expressing local characteristics of each segment and its application to evaluate human thermal responses in water

Shintaro Yokoyama[1], Takafumi Maeda[1], Masashi Kuramae[1], Hitoshi Wakabayashi[2] and Takeo Nomura[3]

[1] Hokkaido University, JAPAN

[2] Kyushu University, JAPAN

[3] Tsukuba University, JAPAN

We introduced a computer program developed for the numerical analysis of thermal conditions of all segments and blood circulatory systems in the human body in order to make a precise evaluation of human thermal physiological responses. In the present program, a cylindrical model, which consists of internal multi-layers, is adapted for the segment of the human body. For the multi-layered concentric cylindrical model we adopted a new numerical solution method. By using the present computer program the internal tissue temperatures, heat fluxes and blood temperatures of all segments in the human body could be calculated simultaneously. The present program also included a subroutine of calculation of thermoregulatory response. This paper describes the outline of the program and its improved assignment and calculation procedures in water immersion and exercises. By using the improved computer program the whole body temperatures and heat fluxes of the subject with several types of clothing during underwater ergometer works were simulated. The calculated results were well agreed with the measured results. It was indicated that the improvement of a prediction computer program of whole body temperature was effective.

Keyword: *mathematical model, whole body temperature, heat fluxes, thermal responses, in water*

INTRODUCTION

We have been developing a prediction computer program of whole body temperatures and heat fluxes expressing local characteristics of each segment in order to apply to making a precise evaluation of human thermal responses (Yokoyama et al., 1997, 2002, 2007a).

This paper describes the outline of the program and its improvement point. The main improved part of the program was the assignment and calculation procedures in water immersion and exercises. By using the improved computer program the whole body temperatures and heat fluxes of the subjects during water immersion works were simulated.

MATHEMATICAL MODELS

Human body is divided into 16 segments (see Figure1, left). Each segment is subdivided into five function layers; viscera, bone, muscle, fat and skin layer. The right side in Figure 1 shows a multi-layered model to adopt for the extremities. The assigned parameters of thermal properties of each layer in the present study were determined according to the previous study (Yokoyama. 1993, 2007b). Inflow and outflow of blood play very important roles for heat transfer phenomena in the body (Yokoyama et al., 2000b). Figure 2 is the schematic diagram showing the circulatory system. In Figure 2 symbols A and V mean the arterial and venous blood pool, respectively. In each segment a pair of large arterial and venous blood pool corresponds to the larger artery and vein. In each layer a pair of arterial and venous blood pools corresponds to the smaller arteries and veins and the capillaries.

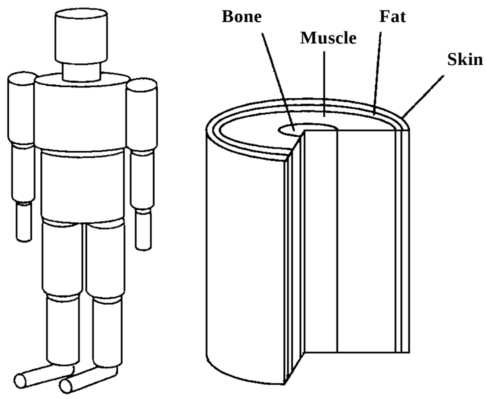


Figure 1. Sixteen segments human body model and multi-layer concentric cylindrical model.

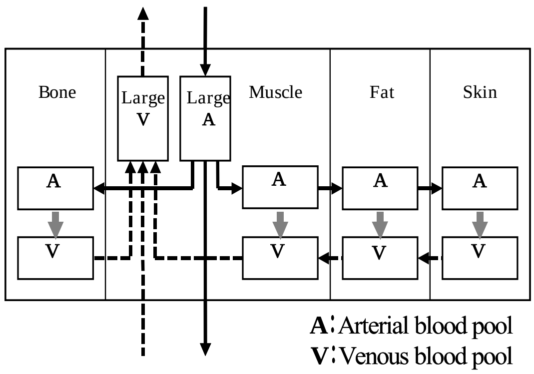


Figure 2. Schematic diagram showing the geometric arrangement of the circular system.

For the prediction of body temperatures and heat fluxes in the human body a solving procedure of heat transfer equation of each segment in the human body is required. We presented an algorithm for saving computing time of the present multi-layered concentric cylindrical model (Yokoyama et al., 1997).

The present program also included the calculation parts of thermoregulatory responses, i.e. perspiration rate, skin blood flow rate, and shivering heat production rate of each segment. The precise values of the parameters of thermoregulatory response were adopted from our previous reports.

Using both compatibility and equilibrium conditions between their interfaces the final simultaneous equations of the whole subject region should be introduced. At the skin surface outflow of heat flux is equal to the sum of heat loss to the environment, convection, radiation and insensible evaporation.

EXPERIMENTAL METHOD

Subjective experiments were carried out and the thermal physiological data concerning with water immersion were collected for the purpose of verifying and improving the accuracy of the present prediction computer program.

A healthy male subject participated in the experiments. The physical characteristics of the subject are summarized in Table 1. After at least one hour spending with resting posture in the test room the subject immersed in water up to the neck level, then pedalled underwater ergometer for 30 min at 60 rpm pedalling rate. The subject wore two kind of clothing. First one was an ordinary swimming suit (SS) (see Figure 3). The second one was a thermal swimsuit (TS)

Table 1 Physical characteristics of the subject

Age	[years]	24
Height	[cm]	172
Weight	[kg]	67
Body Surface Area	[m^2]	1.61
Body Density	[kg/m^3]	1.06
% Fat	[%]	15
Lean Body Weight	[kg]	57

Figure 3 Experiments for ordinary swimming suit (SS)

Figure 4 Experiments for thermal swimsuit (TS).

made of nylon faced neoprene (2mm), consisted of jacket (front zip) and pants, covered trunk, upper arms, thighs and neck (see Figure 4). The thermal conductivity of wetted texture measured with the hot plate method was 0.11 [W/m K].

The esophagus temperature, the rectal temperature, and ten-point skin temperatures were measured by thermistors. Total metabolic rates were measured with the breath-by-breath method. In addition electromyograms of the main seven muscle groups were measured to identify local muscle metabolic rates. Measuring thermal environmental factors were air temperature (T_a), mean radiant temperature (T_r), air velocity (v_a), relative humidity (RH), water temperature (T_w) and water current velocity (v_w).

SIMULATION METHOD

Our previous computer program consisted of main six procedures. 1) Assigning physical characteristics of the subject and thermal properties of each segment, 2) Assigning the thermal environmental factors of each segment, 3) Calculation procedure of thermoregulatory response outputs, 4) Calculation of heat exchange between each segment and thermal environment, 5) Calculation of arterial and venous blood temperatures of each layer and segment and 6) Calculation of whole body tissue temperatures and heat fluxes.

We made several efforts to improve the previous computer program. One of important points was a new assigning procedure of local muscle metabolic rates for underwater ergometer exercises. We assigned them according to our prediction method with total metabolic rates and integrated electromyograms of main muscle groups. We also improved our computer program to calculate temperatures and heat fluxes of each segment in water immersion and with wetted clothing.

The above mentioned assignment and calculation routines were built into the present program.

COMPARISON OF CALCULATED AND MEASURED RESULTS

In case of ordinary swimming suit (SS)

The experiments concerning ordinary swimming suit (SS) was performed under T_a 27.9°C, T_r 27.9°C, RH 52.2% and v_a around 0.1m/sec. T_w was 26.3°C. There were large differences of relative v_w between active segments and static segments in underwater ergometer exercises. The foot segment had the largest v_w of 1.07m/sec. The v_w value of the cruse and the thigh were 0.87 and 0.44 m/sec, respectively. The v_w values of the other static segments were around 0.1m/sec. Total metabolic rate of underwater ergometer exercises was 275[W].

In Figure 5 the measured and calculated results of the esophagus and the mean skin temperature are summarized. Figure 6 shows the comparison of measured and calculated results in the case of ordinary swimming suite (SS) after 30min in water immersion.

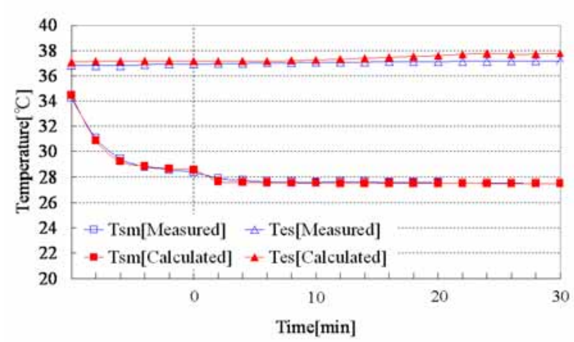


Figure 5. Measured and calculated results in the case of SS.

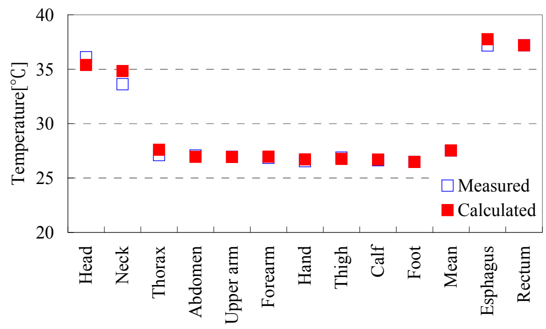


Figure 6. Comparison of measured and calculated results in the case of SS after 30min.

Although the head skin temperatures after water immersion was the same level compared with that at rest in air, the skin temperatures of the foot and the cruse segments under water suddenly decreased and closed with the level of water temperature 26.3°C after water immersion. The mean skin temperature at rest in air was 34.26°C and dropped to 27.51°C after 30 min shown in both Figure 5 and 6. The esophagus temperature in water immersion of thirty minutes was almost the same level as 37°C at rest in air and maintained a somewhat rising tendency due to the effect of the underwater ergometer exercise. The esophagus temperature after 30 min was 37.18°C.

By using the present advanced computer program the simulation results of esophagus temperature and mean skin temperature were in well accordance with the measurement values (see Figure 5). Although the small differences between the calculated and measured of the neck skin temperature was observed, the present program could afford the more accurate whole body temperatures.

In case of thermal swimsuit (TS)

The experiments concerning thermal swimsuit (TS) was performed under T_a 28.2°C, T_r 28.2°C, RH 54.8% and v_a around 0.1m/sec. T_w was 26.4°C. The values of relative v_w of each segment and total metabolic rate ware the same as those in the case of SS. On the other hand the thermal insulation values increased in the case of TS. Especially the upper and the lower trunks, the upper arm and the thigh segments had the additional thermal resistance value of 0.09 [clo] induced with the present thermal swimsuit in water immersion.

In Figure 7 the measured and calculated results of the esophagus and the mean skin temperature are summarized. Figure 8 also shows the comparison of measured and calculated results in the case of thermal swimsuit (TS) after 30 min in water immersion.

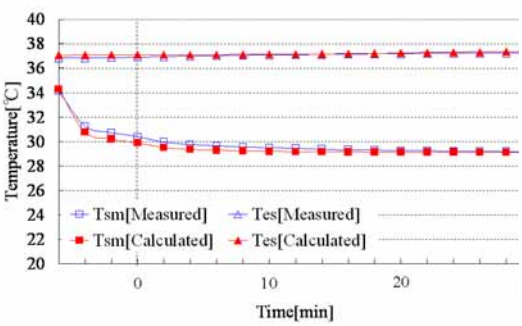


Figure 7. Measured and calculated results in the case of TS.

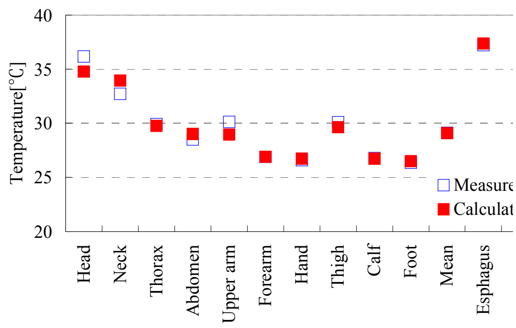


Figure 8. Comparison of measured and calculated results in the case of TS after 30 min.

The head skin temperatures after water immersion was the same level compared with that at rest in air. The skin temperatures of the foot and the cruse segments under water suddenly decreased and closed with the level of water temperature 26.4°C after water immersion. The mean skin temperature at rest in air was 34.14°C and after 30 min reached to 29.51°C which was higher than that in the case of SS. The esophagus temperature in water immersion of thirty minutes was almost the same level as 37°C at rest in air and maintained a somewhat rising tendency due to the combined effect of the underwater ergometer exercise and thermal insulation. The esophagus temperature after 30 min reached to 37.25°C which was higher than 37.18°C in the case of SS.

In the case of thermal suit (TS) the calculated results were well agreed with the measured results shown in both Figure 7 and 8. It was indicated that improvement of a prediction computer program of whole body temperature was effective.

ACKNOWLEGEMENTS

This research was supported in part by a Grant-in-Aid for Scientific Research (No.16207017) from the Japanese Society for the Promotion of Science.

REFERENCES

1) Yokoyama, S. (1993). Bio-heat transfer phenomenon within the human body (in Japanese). Hokkaido university press.

2) Yokoyama, S., Kakuta, N. and Ochifuji, K.(1997). Development of a new algorithm for heat transfer equation in the human body and its applications, Appl. Human Sci., 16, 153-159.

3) Yokoyama, S., Kakuta, N., Togashi, T., Hamada, Y., Nakamura, M. and Ochifuji, K. (2000a). Development of prediction computer program of whole body temperature expressing local characteristics of each segment: Part 1 Bio-heat equations and solving method, Trans. SHASE, 77, 1-12.

4) Yokoyama, S., Kakuta, N., Togashi, T., Hamada, Y., Nakamura, M. and Ochifuji, K. (2000b). Development of prediction computer program of whole body temperature expressing local characteristics of each segment : Part 2 Analysis of the mathematical model for the control of skin blood flow. Trans. SHASE, 78, 1-8.

5) Yokoyama, S., Kakuta, N., Togashi, T., Nakamura MI, Masaki, T., Hamada, Y., Nakamura,MA and Ochifuji, K.(2002). Development of prediction computer program of whole body temperature expressing local characteristics of each segment: Part 3 Comparison of measured and calculated results. Trans. SHASE, 84, 43-52.

6) Yokoyama, S., Tao, M. and Kakuta, N. (20007a). Prediction computer program of whole body temperatures and its application under various working level and thermal environmental condition combinations. Industrial Health, 45, 118-124.

7) Yokoyama, S., Maeda, T., Kuramae, M. and Kakuta, N. (2007b). Human thermal model expressing local characteristics of each segment: J. Human-Environment System, 10, 51-61.

Aquatic mites, collected from swimming pools, and their predicted environmental or medical roles on swimmers

Kazumi Tagami and **Takeo Nomura**

Laboratory of Exercise and Environmental Health, Division of Health and Sport Sciences, Postgraduate School of Human Comprehensive Sciences, University of Tsukuba, Tsukuba, Ibaraki 305-8574, Japan.

ABSTRACT

In this paper, five Astigmatid and four Oribatid submerging mite species, collected from 36 Japanese, 34 European, and 1 Australian indoor swimming pool water, are described. Among these mites, 2 astigmatids and 2 oribatids are common species with European and Japanese pools. They contaminated into the pools through three ways such as swimmer's ware, municipal water supply, and insect vector (smoky brown cockroach, *Periplaneta fuliginosa* (Bllattaria: Bllatidae)). Crude extracts of the pool mites (*Shwiebea elongate*, Astigmata, Acaridae; *Trhypochthoniellus longisetus*, Oribatida, Tripochthoniidae) cross-react with ordinal house dust mite allergen, *Dermatophagoides farinae*, Astigmata, Pyroglyphidae). These mites are resistant to the usual swimming pool disinfectant (0.4 mg/l chlorine). They usually grow on the pool dusts or debris on the bottom floor. To minimize these dusts, we have to maintain the floor clean. These mites are relatively large (about 1 mm long), brownish, and moving objectives, so they are easily detectable on lower magnitude microscopic observation (x 5 to 10). Thus, pool mites are useful biological indicator that the pool maintained more cleaner or safer for the swimmers.

Key words: *swimming pool mites, antigen, Astigmatid, Oribatid, biological indicator, cleaning index*

INTRODUCTION

In 1992, two species of aquatic oribatid mites, *Trhypochthoniellus longisetus* (Berlese, 1904) (Acari, Oribatida, Tripochthoniidae), *Trimalaconothrus maniculatus* Fain and Lambrechts, 1987 (Oribatida, Malaconothridae) and one species of aquatic astigmatid mite, *Histiostoma ocellatum* Fain and Labmrechts, 1987 (Astigmata, Histiostomatidae) were identified from the bottom of swimming pools in Japan (Tagami *et al.* 1992). In March 1992, another mite (*Schwiebea elongata* (Banks, 1906) (Astigmata, Acaridae) was also found in a swimming pool located in southern Ibaraki Prefecture, Japan and it was identified (Okabe and O'Connor, 2000).

Antigenic features of rearing specimens (*Trh. longisetus and S. elongata*) were assessed by radioallergosorbent test (RAST) using sera obtained from swimmers and asthmatic patients. The results showed that the extracts of these aquatic mites crossreact with *Dermatophagoides farina* specific immunoglobulin E (*Df*-IgE). The author concluded that the pool mites were environmental allergens (Tagami, 1995).

It is important to know whether or not the existence of these mites in swimming pools is restricted to Japan. The authors are collaborating with their scientific interests to determine world distribution of swimming pool mites. The first step of this study was performed in Europe from June 1994 to February 1995. The Japanese standards of swimming pool administration originated from German Industrial Standards (DIN, Deutche Industrie-Norm) and are similar to that of European countries.

METHODS

(1) Mites Collection

Thirty six swimming pools in 35 Japanese cities, thirty four pools located in 16 European cities, and one Australian pools were investigated. All pool managers kindly allowed us to collect swimming pool mites from their facilities. An investigator dived into the pools and collected sediments from the bottom of the pools with a handy square net (0.1 m (V) x 0.1 m (H) x 0.5 m (L), made from a 20 x 20 μm nylon mesh screen) with a 0.6 m handle rod. All sediments collected by this way, were transferred into a 50 ml tube containing 70 % alcohol. The specimens were brought to our laboratory, sorted binocularly, and identified microscopically.

(2) Treatment of the specimens

Oribatid mites were isolated from the alcohol fixed sediments using 10 to 50 times magnitude binocular microscope, the numbers determined, and specimens were mounted on glass slides with Hoyer's solution with no other pre-treatments. The mounted specimens were observed at a magnitude of 400 to 1000 times after making them translucent.

Astigmatid mites were isolated similarly and pre-treated with clearing solution mixture (Keifer's formula). The treatments consisted of mild heating until they become translucent, addition of equal volumes of Hoyer's solution to the mixture (Keifer, 1953), and transfer of the translucent mites to a new Hoyer's solution to prevent body puncture and to accelerate de-coloration of the brownish iodine from Keifer's solution.

(3) Identification

Trhy. trichosus was identified by Dr. Jun-ichi Aoki (Professor Emeritus, Yokohama Kokuritu University). The other Oribatid specimens, *Tricoribates setosus* (Ceratozetidae), *Trh. longisetus* and *Trimalaconothrus maniculatus* (Malaconotridae) were identified by the autors, but *Schwiebea elongata* (Acaridae, Astigmata) was identified by Dr. Kimiko Okabe (National Institute of Forest and Forestry of Japan), Dr. Kazuyosi Kurosa (Toshima-ku, Tokyo) and Dr. Barry M. O'Connor (Museum of Zoology, University of Michigan). *Histiostoma nigrellii* and *H. ocellatum* were identified based on the keys described by Hughes and Jackson (1958), and Fain and Lambrechts (1987) by Tagami.

(4) Ways of contamination into pools

The possible ways of invasion or contamination are water supply, air or flying insects, and swimmers. Black swim wares, supplied pool users who swim two times in a day, were microscopically tested. The water (2000 m^3) supplied into a pool was filtered through 20 μm mesh, and the residues were sorted and collected objects were identified (Tagami et al. 1995). Trapped cockroaches near the pools were placed on potato dextrose agar medium and maintained a few days, then, obtained mites were identified as above (Tagami, 2007).

(5) Allergenicity

Supernatants of phosphate buffered homogenate of rearing or growing mites, collected from swimming pools, were accessed to radioallergosorbent test (RAST) to evaluate their allergenicities. The sera obtained from 32 swimmers and 43 randomly selected , healthy non-swimmer athletes were investigated by RASTs to two species of swimming pool mites, *Trhypochthoniellus longisetus* (Hc; Oribatida, Tripochthoniidae) and (*Schwiebea elongata* (Sch; Astigmata, Acaridae), and a usual house dust mite *Dermatophagoides farinae* (Df; Astigmata, Pyroglyphidae). Positive rates of RAST for Sch, Hc, and Df were 28.1, 25.0 and 59.4% in swimmers, and 31.8, 31.8 and 63.6% in non-swimmers, respectively (Figure 1). Both Hc- and Sc-RAST reactions were similarly inhibited by the addition of Sch, Hc and Df antigens. Df_RAST was inhibited by Df itself, but not by Sch and Hc antigens (Table 1). These results showed that swimming pool mites have active allergenic components common with those of Df.

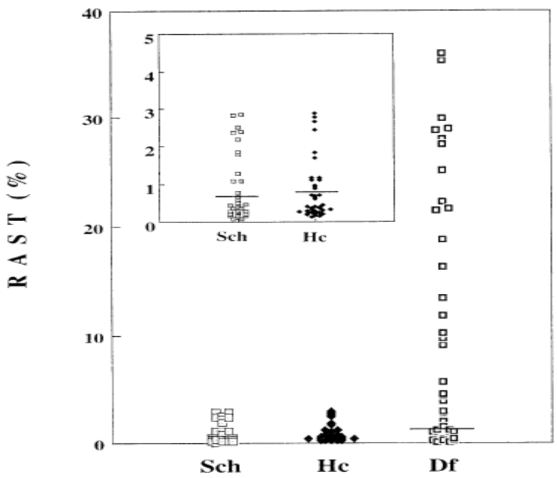


Figure 1. RAST values for *Schwiebea* sp. (Sch). *Hydronothrus crispus* (Hc),and *Dermatophagoides farinae* (Df) in 43 healthy, non-swimmer athletes. The Y axis in set figure is 5 times enlarged to show greater resolution of Sch an Hc. The marks (-) on the figure stand for cut-off value (Modified from Tagami, 1994).

Table 1. Results of Sch-, Hc- and Df-RAST inhibition test (Modified from Tagami, 1994).

Antigen	Inhibitor	% inhibition
Sch	Sch	96
	Hc	94
	Df	96
Hc	Sch	97
	Hc	95
	Df	98
Df	Sch	−2
	Hc	4
	Df	97

Prior to the RAST assay, the test serum was mixed and preincubated with inhibitor solution, and the 50 μl of the serum was subjected to the three RAST assays. The antigens (1 mg) were coupled to 200mg CNBr activated Sepharose 4B.

(6) Pool cleaning procedure and the cleaning index

During four month interval, an indoor swimming pool (pool A) was cleaned twice with an automatic robot type cleaner (Mariner aps2000, 3/S Systemtechnik, Switzerland) and another pool (pool B) was vacuumed only once with a manual cleaner (Type SP-83, Yotsuyanagi Co., Osaka & Mitaka, Japan).

The number of mites in the pool dusts collected manually as shown in 'collections' from five sites of the pools, before and after the cleaning was counted binoculalarly. The count was performed with a 10 times magnitude binocular with multiple lighting. The pool dust specimen (about 1 g wet weight) was placed into a 90 mm glass dish and added some water (3-5 mm depth). The living and dead mites with legs were counted but dead mites without legs were not counted.

After the count, the contents of the dish were collected on desiccated and weighed filter paper. The dry weight of the pool dust was given as a total weight after 50 ^{o}C, 24 hour desiccation minus the filter paper weight. The number of mites was divided by the dry weight of the pool dust, thus the density (number of mites / g dry dust) and the mean value of the 5 sites in pools was calculated before and after cleaning.

RESULTS and DISCUSSION

(1) Identification of European swimming pool mites

We collected 2500 mites, consisting of 9 species from 2 suborders (Astigmata and Oribatida), from 34 European indoor swimming pools. The astigmatids consisted of 3 families (5 species from 4 genera) and the oribatids also consisted of 4 families (4 species from 4 genera). The details are shown in Table 2. Five European swimming pool mites (3 astigmatids and 2 oribatids) are not shown in Japanese pools (Tagami, 1992). The remaining 4 species are common species those shown in Japanese swimming pools. We did not succeed to identify *Acarus* sp. isolated from Stochholm, because alcohol immersed specimens of this group of mites were very difficult to make clear enough for microscopic observations. We also did not decide it's species of one *Histiostoma* sp. isolated from Humburg, because the sample number was too small.

Table 2. Result of identification and quantity of swimming pool mites collected from European swimming pools from 1994 to 1995.

Location	Species and quantity of swimming pool mites in Europe	
	Species of swimming pool mites	Quantity
Stockholm A	*Schwiebea elongata*	2
	Histiostoma nigrellii	809
Stockholm B	*Acarus* sp.	55
	Schwiebea elongata	25
Uppsala	-	-
Brussels A	*Trim. maniculatus*	7
	Histiostoma ocellatum	7
Brussels B	*Histiostoma ocellatum*	6
Brussels C	*Schwiebea elongata*	119
Brussels D	*Tric. setosus*	5
	Trhyp. longisetus	26
	Histiostoma ocellatum	21
Brussels E	*Schwiebea elongata*	3
London	-	-
Hamburg	*Histiostoma* sp	7
Berlin	*Histiostoma ocellatum*	19
Leiptich	-	-
Munchen A	*Trhyp. longisetus*	90
	Trim. maniculatus	13
Munchen B	-	-
Munchen C	*Trhyp. trichosus*	98
	Trim. maniculatus	32
Wienna A	*Trhyp. longisetus*	104
	Trim. maniculatus	28
Wienna B	*Trhyp. longisetus*	35
	Trim. maniculatus	28
Wienna C	*Trhyp. longisetus*	202
	Histiostoma nigrellii	552
Wienna D	-	-
Zurich A	*Trim. maniculatus*	28
	Histiostoma ocellatum	12
Zurich B	*Trhyp. longisetus*	11
	Trim. maniculatus	81
Zurich C	*Trim. maniculatus*	7
Geneva A	*Trim. maniculatus*	18
Geneva B	-	-
Geneva C	-	-
Geneva D	*Schwiebea elongata*	10
	Histiostoma nigrellii	73
Piacenza A	*Histiostoma ocellatum*	1
	Schwiebea elongata	2
Piacenza B	-	-
Piacenza C	-	-
Piacenza D	*Histiostoma nigrellii*	20
Amsterdam	*Trim. maniculatus*	194
Canberra	-	-

Histiostoma nigrellii Hughes and Jackson, 1958 has been characterized by finely granular and sometimes minute projections giving a fuzzy appearance on the dorsal hysterosoma (Hughes and Jackson, 1958). Our specimens showed morphological similarities in male and female, however, half of the females had no projections on their hysterosomas. Therefore, we were unable to identify this species because the projections did not possess important characteristics.

Here, we identified another histiostomatid species of *Histiostoma ocellatum* Fain and Lambrechts, 1987, despite of difficulty in separating the species from *H. cyrtandrae* (Vitzthum), 1931. *H. ocellatum*, which was collected from an aquarium containing Discus fish, in Antwerp on December 1985, and recorded as a new species based on 4 morphological differences, the shape of bursa copratrix, the size and the chitinized pattern of propodotonal shield, distance differences between inner and outer propodotonal setae, and tibial chaetotaxic differences. *H. cyrtandrae* was once redescribed in 1958 by Hughes and Jackson from New York, however, the identification is controversial (Fain and Lambrecht, 1987). Therefore, we temporarily identified the specimens collected from European indoor swimming pools, as *H. ocellatum* Fain and Lambrecht, 1987 until their ontogeny or deutonymph will be studied further.

H. ocellatum, *H. nigrellii*, and *S. elongata* (Astigamata), *Trim. maniculatus*, *Trhy. longisetus* and *Trhy. tricosus* (Oribatida) have been described in their swimming pool bottom habitat. This submerging aquatic habitat would be a new for *Acarus* sp. and *Tric. setosus*. These mites have been mostly detritiphagous (mold, algae, bacteria, etc.). The mite growth is an evidence of the existence of bio-flora in the pools in spite of relatively higher concentration of chlorine (0.4 mg/l).

(2) Application of swimming pool mites as an indicator of pool cleaning

Submerged dust or debris on the bottom of pools are usually controlled/trapped with some type of vacuum cleaners or water circulation and filtration apparatus. Despite these efforts to eliminate mites, the occurrence of swimming pool mites in most pools of Japan and Europe may be due to insufficient cleaning, miss-operations of cleaner or both.

We performed pool cleaning with an automatic vacuum type cleaner robot and a manual cleaner to understand why swimming pool mites/dusts are not eliminated completely. Performances were indicated by a decline in pool mite density (number count / g dried pool dust) between pre- and post-cleaning. The mean cleaning efficiency (mean density of post-cleaning / mean density of pre-cleaning) was 0.2 to 0.5 in our 3 trials. The swimming pool cleaner acted well because most visible dusts were eliminated by both cleaning, however, the efficiency was relatively smaller than our expectations. This might be a reason why it is difficult to eliminate pool mites by these cleaning procedures. Although, the mite count per square unit could be a more suitable index in this case, it will be difficult to collect all sediments because some might be floated or suspended in water by the cleaning actions.

The two pre-cleaning density values were very similar in our study (Figure 2), when the pool was left uncleaned for a period of 4 months or more. The density, about 50 mites/g dried pool dust, might be a maximum in pool habitat. The density of pre-cleaning value in pool B was 10 times higher than that in pool A (Figure 3), mainly because the water had enriched with the dust consisted of woody chips originated from decayed beams beyond the pool. The mites in this pool were all *Trhy. longisetus* which tend to be strictly detritophagous.

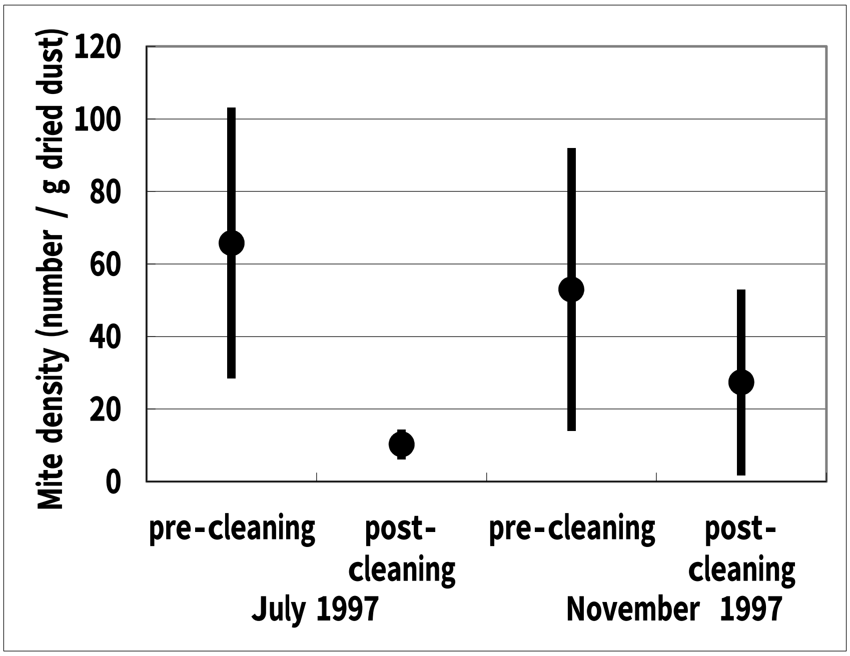


Figure 2. Lowered swimming pool mite density resulted from two pool cleanings with a fully automatic vacuum cleaner (APS-2000, 3/S Systemtechnik AG, Switzerland). These values were obtained by two 4 months interval cleaning.

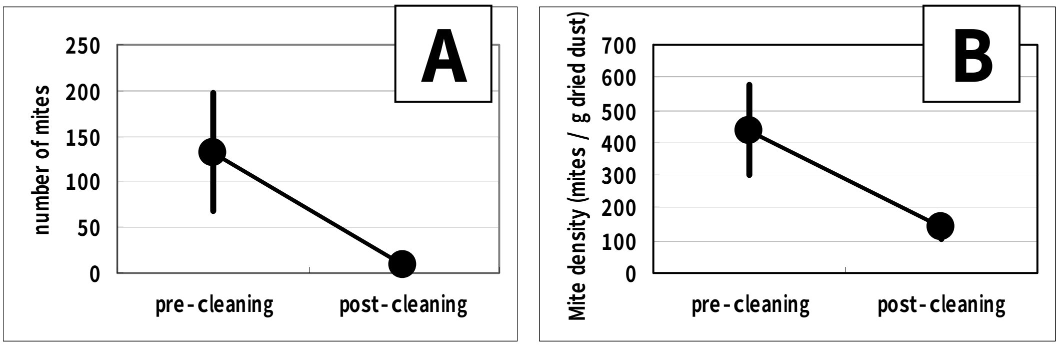


Figure 3. Lowered swimming pool mite number (panel A) and density (panel B) resulted from pool cleaning with a manual vacuum cleaner (SP-83, Yotsuyanagi Co. Ltd., Tokyo & Osaka, Japan).

We found that ordinal vacuum cleaners for swimming pool can eliminate mites, however, the measured cleaning efficiency was relatively lower (70-80%) in this study, and the difference between these two cleaners was not detective. To maintain swimming pools free from mites or other invading small animals, frequent cleaning for sediment debris was recommended.

CONCLUSION

Here, we recorded 4 species from Japan in 1992 and 9 species of mites from European indoor swimming pools during the summer of 1994. They showed weak but evident antigenicity on asthmatic sera. This is an evidence of mite food growth in pools, an undesirable fact for swimmers and pool administrators. We proposed a convenient index of pool cleaning, mite density, obtained ordinal laboratory tools such as filter papers, glass dishes, a hand net, a balance, a binocular and a desiccator.

ACKNOWLEDGEMENT

The authors thank Kankyoukougaku-sya Publishing and University of Tsukuba Research Project for financial or grant support of these studies. We also thank Dr. Alex Fain and Dr. Georges Wauthy (Institut royal des Sciences naturelles de Belgique, Bruxelles), Dr. Marco Pagani (Istitut di Entomologia, Facolta di Agraria, UCSC, Piacenza, Italy), Dr. Barry M O'Connor (Museum of Zoology, University of Michigan), Dr. Kazuyoshi Kurosa (Toshima-ku, Tokyo), Dr. Jyun-ichi Aoki (Professor Emeritus, Yokohama Kokuritu University), Dr. Masamichi Ito (Yokohama Kokuritu University, Yokohama, Japan), Dr. Kenji Fukuyama and Dr. Kimiko Okabe (National Institute of Forest and Forestry of Japan, Tsukuba) for their scientific advises on mites.

REFERENCES

Fain, A and Lambrechts, L (1987) Observations of the acarofauna of fish aquariums. 1. Mites associated with Discus fish. Bulletin et Annales de la Societe Royale Belgique d'Entomologie 123:87-102.

Hughes, TE and Jackson CG (1958) A review of the family Anoetidae. Virginia Journal of Science, 9: 5-198.

Keifer, HH (1953) Eriophyid studies XXI. Bulletin of the California Department of Food and Agriculture 42: 65-79.

Manson, DCM (1972) Three new species, and a redescription of mites of the genus *Schwiebea* (Acarina: Tyroglyphidae). Acarologia 14(1):71-80.

Okabe, K and O'Connor, BM (2000) Morphometric and systematic analyses of populations of the *Schwiebea barbei* – group (Acari: Acaridae) with particular reference to populations from North America and Japan. International Journal of Acarology 26:

115-126.
Tagami, K, T. Ishihara, J-I. Hosokawa, M, Ito, and Fukuyama, K (1992) Occurrence of aquatic Oribatid and Astigmatid mites in swimming pools. Water Research 26(11):1549-1554.
Tagami, K, H Takakuwa, I Sakata, and G Takahashi (1995) A new route of swimming pool mites invasion among pools by swimming suits. Bulletin of Institute of Health and Sport Sciences: University of Tsukuba 18:189-192 (in Japanese).
Tagami, K (1995) Laboratory culture of swimming pool mites and their allergenicities. Japanese Journal of Sanitary Zoology 46(2):125-130 (in Japanese with English abstract).
Tagami, K (2007) Phoretic histiostomatid mites on the smoky-brown cockroach *Periplaneta fuliginosa* (Bllataria: Bllatidae), contained unknown deutonymph of *Histiostoma piscium* (Astigmata, Histiostomatidae). in "Acarology XI: Proceedings of the International Congress" Morales-Malacara, JB, *et al.* (Eds.). Instituto de Biología, UNAM; Facultad de Ciencias, UNAM; Sociedad Latinoamericana de Acarología. México, pp. 35-41.

Between and within race changes in race parameters in swimmers with intellectual disability

Ingi Þór Einarsson[1], Erlingur Jóhannsson[1], Daniel Daly[2]

[1] Center for Sport and Health Science, University of Education, Iceland

[2] Department of Human Kinesiology, Katholieke Universiteit Leuven, Belgium

The purpose of this study was to examine the variability of diverse aspects of freestyle race performance in swimmers with intellectual disability (ID). Sixteen competitors (8 ID and 8 without ID) swam three 200-m freestyle races in competition over a 4 month period. Both groups had similar training background and competitive experience. ID swimmers showed a greater between race variability than the control group in end result (9.9% vs. 6.3% for WID) and mid-pool swimming speed. They also showed a greater variation in the relationship between change in Stroke Rate and change in swimming speed. ID swimmers swam slower and had not only a shorter Stroke Length but also lower Stroke Rate.

Key words: *Swimming, Freestyle, Intellectual Disability*

Introduction

A systematic relationship between intellectual disability (ID) and reduced motor skill unrelated to training or intrinsic talent has not been clearly shown. Athletes with ID are therefore no longer allowed to participate in Paralympic Competition. Previously a large scale project was set up at the Global Games, a multi sport world championship for persons with ID. In comparison to (ID) population data, both male and female Global Games participants scored better for flexibility and upper body muscle endurance, but had similar or lower values for running speed, speed of limb movement and strength measures[1]. When a Wingate cycling test was repeated on two days, boys with ID were significantly more variable and less consistent than boys without ID both in mean and in peak power output[2]. The effect of interference during performance of a dual task was also significantly greater in individuals with ID (IQ=55-76)[3]. This could indicate that swimmers with ID have poorer control over their stress level and other interfering factors might lead to less stable performance for example in starting and turning.

Video swimming race analysis data was also collected at the Global Games competition mentioned above[4]. In short course races, swimmers with ID, although experienced, were more likely to use a deviating within race speed pattern than other populations. This all together with anecdotal evidence suggests that ID swimmers are not only weaker performers but also demonstrate more unstable performance. The purpose of this study was to examine various aspects of performance in ID athletes in a longer short course 200-m freestyle race and see how these changed within and between 3 races.

Methods

Participants were 5 men and 3 women competitive swimmers with intellectual disability and 3 men and 5 women competitive swimmers without intellectual disability (WID). All volunteered to take part and all swimmers or their guardians signed informed consent. The study was approved by the ethical committee of the Iceland University of Education. Swimmers with ID were national team members but not all freestyle specialists and had been classified as eligible for participation by the INAS-FID (see http://www.inas-fid.org/pdf/INASIPCapplication.pdf).

All participants swam 3 or 4 * 200-m freestyle races in national level competitions in 25-m pools over a 4 month period. All races were finals or timed finals. Swimmers were videotaped with 2 digital (25 Hz) video cameras placed perpendicular to the swimming direction at 7.5-m from the start and 7.5-m from the turn. At least 3 complete arm stroke cycles were visible in each camera view. The start signal was used to synchronize the 2 cameras via the sound track. Frame count recording was carried out by experienced persons. Double analysis showed max errors of 1 frame (0.04s) for any race section time or stroke count between and within analysis personnel. Using this information the following were calculated: speed for 8 mid pool Race sections and 7 Turn Times = 5-m from turn (in) to 10-m after turn (out). Movement parameters were also measured for each race section: Stroke Rate (SR) or frequency, and Stroke Length (SL). Each swimmer was asked to judge the intensity of their effort on the Borg scale from 1 to 20.

To describe the participants, M, SD and Min and Max values were determined as well as the coefficient of variation (SD/M). Two-way ANOVAs was used to compare groups and changes over the 3 races (repeated measures, $p < .05$).

Results and Discussion

The purpose of this study was to examine various aspects of race performance in ID athletes in an intermediate distance 200-m freestyle race and see how these changed within and between races. In a 100-m freestyle race ID athletes had demonstrated problems with race pace in a short course pool but not in long course[4]. The 200-m freestyle race requires a combination of both aerobic and anaerobic capacity, so that both "sprinters" and middle distance swimmers could take part.

The two groups (ID and WID) only differed in total 2 hour training sessions per week (6.7 vs 9.2) and thus total km/week and the swimmers without ID did more km/hour. WID swimmers all trained at least 9 times a week while only some of the ID swimmers did this. In absolute terms the WID swimmers were faster even considering the fact that the group was made up of more women. The End Race Result was also compared to the population world record using a point score. Again the ID swimmers scored on average 151 points less than the WID colleagues, indicating not only an absolute but also a relative difference to the advantage of the WID. The range of performance in the ID group was also much higher than that seen in WID swimmers (*SD:* ID = 88pts and WID = 65).

Versichel & Vos[4] stated that successful ID competitors have trained in water at least 4 years and swim at least 10-12 hrs a week over 10 months a year (n=30). Success was defined as 600 performance points in the best event. All ID swimmers in this study met the criteria for training. Only one scored at least 600pts in the 200-m freestyle race but all attained this point limit in other events. All ID swimmers did achieve personal best times in the 200-m free event during this study.

Mean race results are given in Table 1. There was a between race change of 9.9%($\pm$3.8) vs 6.3%($\pm$4.1) in point scores with a real change of 51pts($\pm$19.8) vs 45pts($\pm$33.8) for ID vs WID swimmers (t-test: $p = .09$). The *SDs* of change was comparable. ID athletes might not have sufficient 200-m free race experience.

Table 1. Mean Race Time and, Start, Swim, and Turn Speed for 3*200m free races in swimmers with (ID, n=8) and without (WID, n=8) intellectual disability (best→worst)

	Race 1			Race 2			Race 3		
ID swimmers	*M*	*SD*	*M* %Δ*	*M*	*SD*	*M* %Δ	*M*	*SD*	*M* %Δ
Race Time(s)	159.34	12.16		162.29	13.85		165.17	14.12	
Class point	513	88.01		488	94.55		462	83.93	
Start(s)	9.04	0.58		9.02	0.57		9.30	0.61	
M Speed(m/s)	1.22	0.09	-15.64	1.18	0.10	-18.82	1.16	0.10	-16.53
M Turn(s)	11.91	1.05		12.06	1.10		12.26	1.15	
WID swimmers									
Race Time(s)	124.21	7.13		125.50	7.48		126.98	6.77	
Class point	681	65.81		659	45.77		636	37.73	
Start(ms)	7.55	0.49		7.53	0.50		7.59	0.43	
M Speed(m/s)	1.54	0.07	-27.62	1.51	0.09	-16.54	1.49	0.06	-15.30
M Turn(s)	9.12	0.61		9.18	0.58		9.31	0.62	

**M*%Δ = within race change in mid-pool speed.

All ID swimmers reported maximal Borg scores for all their swims although this raises some doubts about its usefulness in this population. All swimmers were also aware that they were being filmed during the races. Although they received not feedback on results, this external motivation did seem to help ID swimmers concentrate.

There was a low but significant (p<.05) correlation (Spearman) between performance level and absolute change in time between races (.58) but this relationship is no longer significant when relative change (percentage) was considered (.46). Furthermore, this does not hold up at all when the point scores (related to population world record) were taken as measures of performance level (-.15). Therefore it does not appear that end race result changes can be related to the relative difference in performance level between the two groups. Of course due to the fact the water resistance increases with at least the square of velocity the energy cost of small increases of speed at high velocity are greater than a larger increase in velocity at a lower speed. Smaller percentage changes in race time could still indicate an equivalent differences in power output making point score changes more meaningful.

The percentage changes in mid pool speed between races were greater in both groups than those of end race result although no changes were significant (4.5% ±2.5 vs 2.9% ±2.5). These changes were almost entirely due to changes in SR in WID swimmers but this was not the case in ID swimmers (2.4% ±5.3 vs 4.3% ±4.08 with increased speed) (1.0 stroke vs 2.0 strokes/min). There was no relationship between changes in SL and changes in speed in any group studied here and this agrees with previous findings for swimmers with locomotor disabilities[5]. So ID swimmers have problems adjusting their movement frequency, for most swimmers their primary means of increasing and adjusting swimming speed within and on the short term between races[8].

The between race changes in turning speed were lower in both groups studied here than those for mid pool speed. ID swimmers showed larger changes than seen in the WID group. Turning was actually a greater part of the race than swimming in the 25-m pool (7 * 15m = 105m turning, 8 * 10m + 5m = 85m swimming). Nevertheless, the R^2 between changes in end race result and changes in total swimming time between races is .94 in WID swimmers and .78 in ID swimmers. The R^2 of changes in turning time are .66 and .44. This indicates that changes in swimming speed are clearly more responsible for total race improvement in all swimmers but that there are more diverse solutions in ID swimmers.

Results also suggest that ID swimmers have trouble in the turning action (somersault) itself and much less so in the push-off. He or she has to judge the wall distance and carry out the turn at the best moment for an optimal position to push off. Furthermore most swimmers can only turn with right or left hand. A swimmer of course does not always get to the wall with the best hand forward. So turning is complicated by itself and requires judgement only to be gained by experience. ID swimmers have more trouble when a skill requires quite adaptation to the situation. They are not able to take sufficient advantage of experience.

There was no difference between groups in within race speed fluctuation as given by the *SD* of within race speed (F = .25). There was a significant difference in this variation between race 1 (fastest) and 2 (F = 6.82 (14,1) p = .02 *ES* = 0.26). The variation increased with better performance. WID swimmers demonstrating greater within race speed variation. The larger variation in this parameter in the WID group does question the validity of the use of swimming speed in this calculation. Furthermore there are large *SD*s (50% of mean) for all within race speed changes indicative of large individual variations in both groups (or low measurement sensitivity). There actually does not appear to be a fixed race speed pattern in either group for a short course 200-m free race.

There is also no significant difference between groups in within race variation in SL (F = .37). There is also no relationship between within race variation in SL and speed. Again there does not appear to be a fixed pattern of changes in SL within the race or between races in ID swimmers. Swimmers with ID, however, did exhibit a significantly greater within race fluctuation of SR (F = 6.78 (14,1) p = .021 ES = .32). Although SR fluctuation increases slightly but unsystematically with increased swimming speed in both groups this was not significant between the fastest (race 1) and slowest (race 3) races (but from 2-3, p = .07). Again there are large SDs for change indicating large inter-individual differences in within race changes in SR. More work is needed to evaluate individual patterns over several races but the differences in within race changes in SR between groups, again together with the slower SR in ID swimmers, points to problems in coordination.

REFERENCES

1. Van de Vliet P, Rintala P, Fröjd K, Verellen J, Van Houtte S, Daly D, Vanlandewijck Y. (2006). Physical fitness profile of athletes with intellectual disability. Scandanavian Journal of Medicine and Science in Sports. 16(6):417-425.
2. Chia Y H M, Lee K S, Teo-Koh. (2002). High intensity cycling performance of boys with and without intellectual disability. Journal of Intellectual & Developmental Disabilty. Vol. 27, No. 3, pp. 199-200.
3. Mohan A, Singh A.P. Mandal, M.K. (2001). Transfer and interference of motor skills in people with intellectual disability. Journal of Intellectual Disability Research.Vol. 45 361-369.
4. Versichel H, Vos L. (2006). Race success in swimmers with intellectual disability. Unpublished Master's thesis, Katholieke Universiteit Leuven, Leuven, Belgium.
5. Daly D, Djobova S, Malone L, Vanlandewijck Y, Steadward R. (2003). Swimming speed patterns and stroking variables in the Paralympic 100-m freestyle. Adapted Physical Activity Quarterly, 20, 260-278.
6. Stallman RK. Kjendlie P. (2006). The stroke length, frequency and velocity among university physical education students and its use as a pedagogical tool. In Vilas-Boas, J.P., Alves, F., Marques, A. (Eds.). Biomechanics and Medicine in Swimming X. Portuguese Journal of Sport Sciences, Porto, Portugal: 6, 268-270.

Oral presentation

Day 2 – 26th March

<u>Room 2</u> - (201 B)

Development of Video-Feedback System utilizing SMART system – attempt in private swimming club

Hirofumi Shimojo[1], Yasuo Sengoku[2], Seiji Sugimoto[1], Chikara Miyaji[3], Takeo Nomura[1]

[1] University of Tsukuba, Graduate School of Sports Sciences, Japan

[2] Heisei international University, Research Institute of Sports Science, Japan

[3] Japan Institute of Sports Science, Department of Sports Information, Japan

The purpose of the present study was to develop the Video-Feedback System (V-FBS) utilizing the SMART system in a private swimming club. The V-FBS is a system to provide feedback information along with underwater swimming motion during swimming training. The V-FBS utilization period was set for six-month. Eleven junior competitive swimmers attending in the private swimming club participated in this study (group utilizing the V-FBS: EX n=4, group merely taking part in the ordinary training session: CON n=7). Results of high attendance rate and larger training volume might indicate that the V-FBS could contribute to sustain the swimmers motivation to participate training. Questionnaires results indicated that swim image was recalled from the training diary and the movies for the swimmer. Consequently, we devised an ideal motor learning model for coaching field.

Key words: *Video, Feedback, Swimming club*

INTRODUCTION

The competitive swimming requires the swimmers' specific motor skills to create propulsion while keeping the resistive forces low. Swimming has a specific feature that it is hard for swimmers to recognize their own under water swim motions. So it is important for the swimmers to get feedback information by their coach. The coaches have used methods for providing feedback information in general coaching field by talking, acting swimmer's motion, filming the swimmers for presentation. Their performance was enhanced by the coach with feedback information toward correcting the swimmers' motions. Bunker et al. (1976) reported the effectiveness of visual feedback for flutter kick instruction. It is considered that visual feedback is important to learn swimming skills for the swimmers.

Nowadays, the Internet network has been enhanced day by day and transaction of video contention have been enabled via the Internet. This enhanced environment affects movie utilization of sport. Japan Institute Sport Science (JISS) presented a new interactive movie database system (SMART system). SMART system was abbreviated for Sport Movement Archiving Requesting Technology system and was a movie feedback system via the Internet using the Internet streaming technology and enables users to search the required movie by the prepared criteria (athlete's name, discipline name, event name, etc.). And the SMART system has an original function called "Annotation" which enables the user to draw and type additional information into the movies. Although this system had been utilized in competition sport scene, this system has not been utilized in the coaching field.

The purpose of the present study was to develop the Video-Feedback system (V-FBS) utilizing the SMART system in the private swimming club. The V-FBS was aimed to provide feedback information along with underwater swimming motion during swimming training for the swimmers to enhance their performance effectively.

METHODS

1. Subjects and period

Eleven junior competitive swimmers attending in a private swimming club participated in this study (group utilizing the V-FBS: EX n=4, group merely taking part in the ordinary training session: CON n=11). The filming and the observation were conducted once a week at the private swimming club. The V-FBS utilization period was set for six-month.

2. Filming

Under water CCD cameras (T-WATER 1100C, Tsukamoto Musen) were utilized with custom made fixed tools which were able to set easily at the pool side (Fig. 1). These tools were designed to enable pan filming, without interrupting swimming program. The swimmers were filmed by two directions. Front side were filmed by a fixed camera, and pan filming were utilized for lateral side.

Fig. 1 Custom made fixed tools with under water CCD cameras.

3. Editing

Before movie files were saved in the streaming sever, the movie files were edited by the author to separate and combine for categorization. The movies were ready for observation via the Internet, and the coach's feedback information was added by author with "Annotation". The Annotation expressed lateral information by text or arrow and line drawn into the movies (Fig. 2).

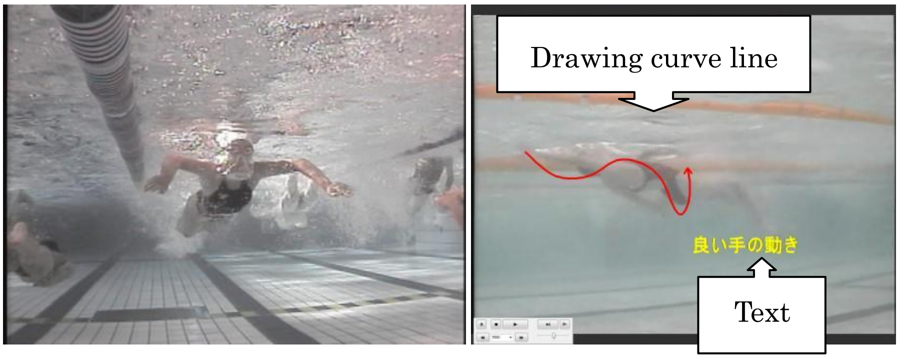


Fig. 2 These pictures indicate the under water movies shots and utilization of Annotation.

4. Observation

Before the training, the swimmers read training diaries which they had noted after every lesson, and observed the movies and information to enhance swimmers' performance via the internet within 30 minutes at the swimming club room. The swimmers and the author were in this room when the observation was conducted. We did not expound the information edited inside the movie, but instructed swimmers how to use the PC.

5. Training diaries

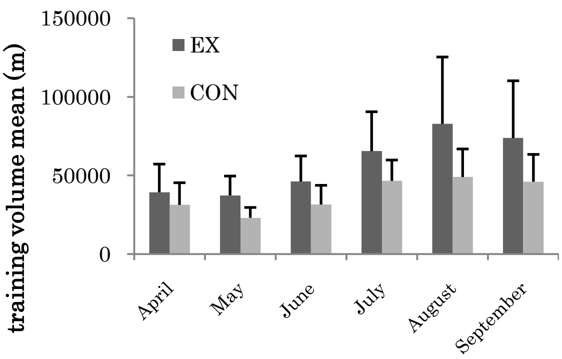
At the end of the training, the swimmers noted the training dairies to keep remembering the swimmers' motor image and kinesthesia in water.

6. Measurement

At the end of the V-FBS period, the access logs of utilization was analyzed and the swimmers filled in the questionnaires about the V-FBS. Amount of swimming work and an attendance rate from training diaries were analyzed.

RESULTS AND DISCUSSION

The V-FBS required assistance to prepare cameras, editing movies, analyzing access logs. This result indicated that we must to reduce management time and to simplify handling equipments for the V-FBS. Coaches' time is limited in coaching for their other works (office work and instructing other members, etc.). If the V-FBS operation times become shorter and more effective to swimmers performance, the V-FBS will be demanded by the coaching fields. The EX attendance rate was kept high and training volume was larger than CON (fig. 3, fig. 4). These results might indicate that feedback information of the V-FBS could contribute to sustain the swimmers motivation to participate training. The movies were added as feedback information by author in this study. Although the V-FBS required assistance, we recommend that coach should at least edit additional information in the movies than others. It was suggested that if both information in the coaching field and in Annotation of the V-FBS were matched, the V-FBS could sustain the swimmers motivation to participate training much higher.



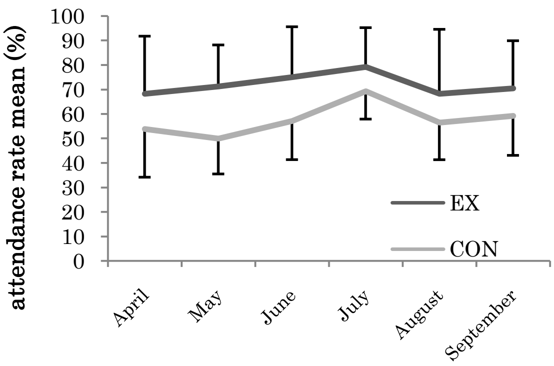


fig. 3 the swimmers training volume (m) fig. 4 the swimmers attendance rate (%)

By questionnaires, the swimmers responded that the training diaries recalled the swimmers' image and kinesthesia clearly. And we were able to investigate the swimmers' notion from training dairies. Analyzing method of access log data should be simplified because the access log date would indicate coaches to know what the swimmers were interested in. And if access log dates are able to show the observing situations clearly, the swimmers will utilize the V-FBS anywhere.

CONCLUSION

This study indicated that the V-FBS could contribute to sustain the swimmers' motivation to participate training by additional feedback information. Consequently, we proposed the ideal V-FBS motor learning model for coaching field (Fig. 5). This model indicates that the V-FBS help the swimmers' motor learning in training. The motor learning is enhanced by swim kinesthesia recalled from the movie observation and training diaries. When the coaching feedback and Annotation feedback are matched in the swimmers' mind, both feedbacks could motivate the swimmers to practice in training and to observe swim motion further.

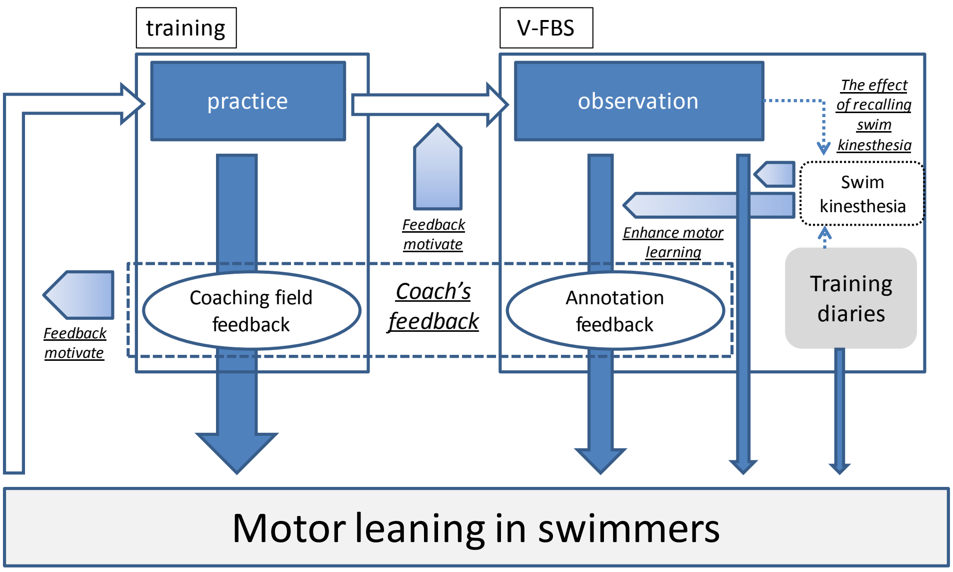


Fig. 5 Ideal Video-Feedback system motor learning model for coaching field

REFERENCES

1. Bunker, L. K., Shearer, J. D. and Mall, E. G. (1976) Video-tape feedback and children's learning to flutter kick. Perceptual and Motor Skills, 43, 371-374.

Effect of Video-Feedback System utilizing SMART system on junior competitive swimmer's motivation and swimming performance

Yasuo Sengoku[1], Hirofumi Shimojo[2], Seiji Sugimoto[2], Chikara Miyaji[3], Takeo Nomura[2]

[1] Heisei International University, Saitama, Japan

[2] University of Tsukuba, Ibaraki, Japan

[3] Japan Institute of Sports Science, Tokyo, Japan

The purpose of the present study was to identify the effect of Video-Feedback System (V-FBS) utilizing SMART system on junior competitive swimmer's motivation and swimming performance. Eleven junior competitive swimmers attending in a private swimming club participated in this study (Experimental group: EX n=4, Control group: CON n=7, age: 12.0±1.6). Swimmer's under water swimming motion through the training session were filmed once a week and presented to the EX utilizing SMART system one week after. CON merely took part in the ordinary training session. It was indicated that the measurement data were equivalent to 2.49 stroke reduction in EX for swimming 25 m compared to 1.48 stroke reduction in CON. Furthermore EX will exceed 1.5 m for ten strokes in SL improvement (EX: 4 m, CON: 2.5 m). Consequently it was concluded that V-FBS has an effect to improve swimming technique for junior competitive swimmer more effectively.

Key words: *coaching method, computer assisted instruction*

INTRODUCTION

Introducing new technologies to the swimming instruction field has been one of the main concern today. Persyn et al. (2) have demonstrated a computer assisted instruction (CAI) program for kinesiological diagnosis in breaststroke. Sengoku et al. (3, 4) developed a CAI program utilizing the Internet to support swimming instruction in elementary school swimming class. In the previous studies, Internet utilization is reported to enhance childrens' learning motivation and is beneficial for children to set a clear aim for learning swimming.

Also Shimizu et al. (5) presented a new interactive movie database system (SMART system) for synchronized swimming. SMART system is a movie feedback system via the Internet using Internet streaming technology and enables users to search the required movie by the prepared criteria (athlete's name, discipline name, event name, etc.).

SMART system has been utilized in synchronized swimming to feedback the performance image in competition, although this feedback system can also be utilized in the coaching scene. By filming swimming motion in the daily training and storing the movie data to the SMART system, swimmers will be able to obtain feedback information of their own movement and could utilize it for performance enhancement.

The purpose of the present study was to identify the effect of Video-Feedback System (V-FBS) utilizing SMART system on junior competitive swimmer's motivation and swimming performance.

METHODS

1. Subjects

Eleven junior competitive swimmers attending in a private swimming club participated in this study (Experimental group: EX n=4, Control group: CON n=7, age: 12.0±1.6). Swimmer's under water swimming motion through the training session were filmed once a week. The filmed data were compiled and stored to the SMART system and the movie information were presented to the EX one week after. Lap top computer connected to the Internet were prepared at the swimming club, and the swimmers gained feedback information by utilizing V-FBS for thirty minutes before swimming training. CON group merely took part in the ordinary training session.

2. Measurements

Questionnaire survey (Dipca III, TOYO Physical) was conducted to investigate swimmer's psychological competitive ability (motivation test: MT). 50 m time trail (front crawl and swimmer's major stroke) were evaluated as the swimmer's swim performance (SP) and stroke rate (SR) and stroke length (SL) were analyzed in the swimming flume (swimming velocity at 70%, 80% and 90% of the 50m trial, front crawl and swimmer's major stroke).

3. Experiment schedule

Experiment period was set for six-month and Pre-test and Post-test were designed for MT and SP assessment. For MT, Middle-test was also conducted three month after the Pre-test.

4. Statistical analysis

All values were expressed as mean ± SD. Freedman test were used for analyzing investigation difference in each group and Wilcoxon and Bonferroni post hoc test were performed when significant difference were detected. Statistical significance was defined as p<.05.

RESULTS

50 m time trial results improved for both group, although significant difference were not observed (EX: 100.96±3.44%, CON: 102.21±3.39%). SR of front crawl significantly reduced in both group at 90% velocity (EX: p<.01, CON: p<.05, Fig. 1) and SL significantly increased at the identical speed (EX: p<.05, CON: p<.05, Fig. 2).No significant results were shown in MT (Fig. 3).

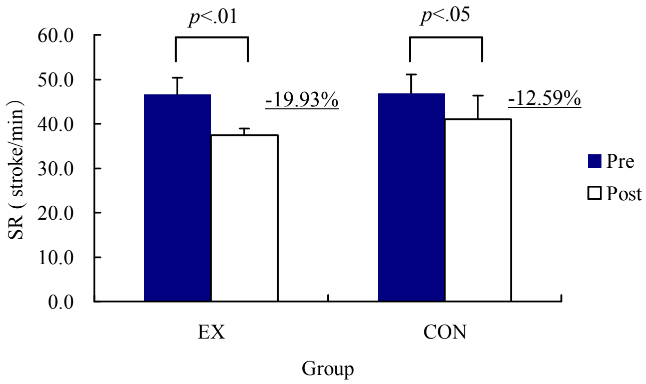


Fig. 1 Comparison of stroke rate investigation (front crawl, 90% velocity of 50 m trial) between Pre-test and Post-test for experimental group and control group.

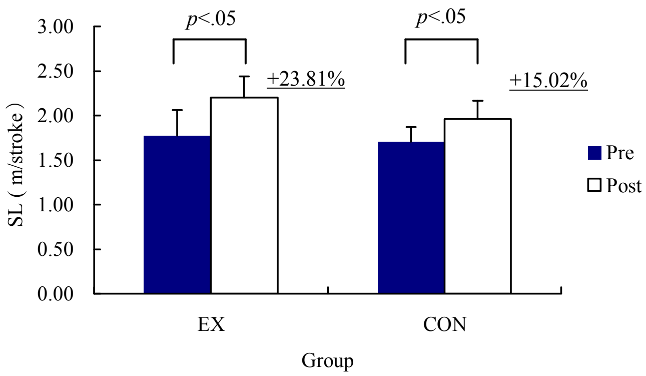


Fig. 2 Comparison of stroke length investigation (front crawl, 90% velocity of 50 m trial) between Pre-test and Post-test for experimental group and control group.

DISCUSSION

Significant difference was not observed between EX and CON for the 50 m time trial. Even EX obtained additional movie feedback information of their own swimming motion, the training session were identical in both groups. As the subjects in the present study were junior competitive swimmers (12.0±1.6 yrs), it can be conjectured that other aspects have influenced the swimmers performance through growth and development. Stroke parameter also represented same tendency in both groups. The reduction in SR and increment in SL at the same swimming velocity indicates improvement in stroke

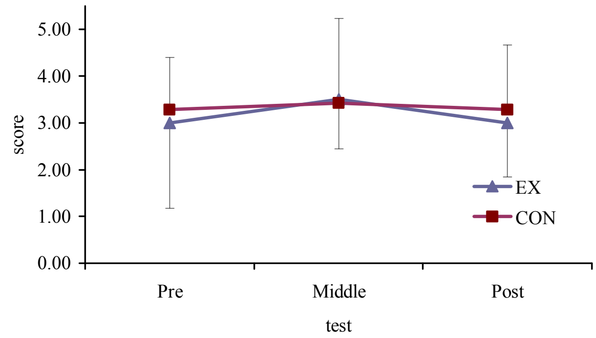


Fig.3 Comparison of motivation test results between Pre-test, Middle-test and Post-test for experimental group and control group.

technique. By converting the data to practical swimming situation, however, EX will reduce 2.49 strokes for swimming 25 m compared to 1.48 stroke reduction in CON. Furthermore EX will exceed 1.5 m for ten strokes in SL improvement (EX: 4 m, CON: 2.5 m). Bunker et al. (1) reported the effectiveness of visual feedback for flutter kick instruction. As the feedback information were presented visually via V-FBS, it can be assumed that swimmer were able to recognize their own swimming movement precisely and resulted in higher technical improvements. Consequently, regarding to practically converted data, it was indicated that V-FBS could improve swimming technique for junior competitive swimmer more effectively.

Previous study stated that CAI program utilized via the Internet has an effect to enhance childrens' learning motivation (4). However, V-FBS did not show any effects on MT. This phenomenon could be explained by the difference in the subject group. The subjects in the present study were competitive swimmers compared to elementary school children in the past literature. There are possibilities that our subjects were highly motivated for swimming performance enhancement from Pre-test investigation.

CONCLUSION

The purpose of the present study was to identify the effect of Video-Feedback System

(V-FBS) utilizing SMART system on junior competitive swimmer's motivation and swimming performance. And from the results, it was concluded that V-FBS has an effect to improve swimming technique for junior competitive swimmer more effectively. Although future studies are warranted to define the appropriate feedback information for swimming instruction.

REFERENCES

1. Bunker, L. K., Shearer, J. D. and Mall, E. G. (1976) Video-tape feedback and children's learning to flutter kick. Perceptual and Motor Skills, 43, 371-374.
2. Persyn U, Colman V (1999). Problems of physical education students in making a kinesiological diagnosis of swimmers : In:Keskinen KL(ed.), Biomechanics and Medicine in Swimming VIII, Finland, Gumnerus Printing, 481-487.
3. Sengoku Y, Ichikawa H, Nomura T (2003). Effect of different computer assisted instruction web site contents on swimming instruction of elementary school children. In:Chatard JC(ed.), Biomechanics and Medicine in Swimming IX, France, Publications de I'University de Saint-Etienne, 592-597.
4. Sengoku Y, Nomura T (2006). Effect of computer assisted instruction web site for swimming to childrens' learning motives and learning strategy. In: JP Vilas-Boas, F Alves, A Marques (eds.), Biomechanics and Medicine in Swimming X, Portuguese Journal of Sport Sciences, Suppl 2, 341-343.
5. Shimizu J, Miyaji C, Ito K (2006) Examination of feedback tool using interactive movie database for synchronized swimming. In: JP Vilas-Boas, F Alves, A Marques (eds.), Biomechanics and Medicine in Swimming X, Portuguese Journal of Sport Sciences, Suppl 2, 262-265.

Innovation in Japanese swimming education

Takao Haruki[1], Takashi Toriumi[2], Hideki Fujimoto[3], Yasushi Ishide[4], Yoshinori Suga[3], Daichi Suzuki[5], Kiyoshi Kurokawa[6]
[1]Faculty of Law, Keio University, Tokyo, Japan
[2]Graduate Schoolof Frontier Sciences, University of Tokyo, Chiba, Japan
[3]Keio Yochisha Elementary School, Tokyo, Japan
[4]Institute of Physical Education, Keio University, Kanagawa, Japan
[5]Schoolof Health and Sports Science, Jundendo University, Chiba, Japan
[6]National Graduate Institute for Policy Studies, Tokyo, Japan

Japanese swimming education has been deflected in technical guidance of competitive swimming up until now. The establishment of comprehensive swimming guidance, including clothed swimming, water treading, and marine sports is needed. This research focuses on clothed swimming for preventing drowning accidents, and is purposed to establish educational guidance. Physiological effects given by clothed swimming will be researched. In-clothes swimming itself and mental practice, heart rate, blood lactic acid, and the Borg score significantly declined.

Key words: *In-clothes swimming, risk management ability, swimming education, water accidents, elementary backstroke, accident prevention*

INTRODUCTION

Each year, about 1000 people are either found dead or missing due to water accidents. Conventional prevention policies for these accidents have focused on keeping people away from dangerous areas. For example, if an area is connoted with the risk of falling into a nearby river, consequent accidents have been prevented by the use of fences. As a result, people became accustomed to life in predominantly safe areas, deprived of situations in which they can hone their risk management abilities, or the ability to recognize danger, to put it in simple terms. Typical examples to demonstrate this point are cases in which individuals considered amply capable of swimming in swimming pools have actually drowned in rivers. It can be speculated that the individual lacked the ability to recognize the difference in the degree and type of danger between swimming pools and rivers.

In order to prevent these water accidents, we deem the following two methods as necessary. The first is to prevent the accident from occurring by taking precautionary measures. Conventional methods kept people away from dangerous areas by building fences around them, or restricting swimming zones at beaches. However, these policies are usually implemented only after an accident has already occurred, and countermeasures are often found to be too late. Moreover, it is impossible to decrease the number of countermeasures unless people's risk management abilities improve. Because of these reasons, it can be speculated that improvement of risk management abilities is crucial in the prevention of water accidents. In order to do this, it is integral to design a mechanism in which people become able to recognize the danger that an environment conceives. To be more specific, we propose a policy, in which dangerous zones are categorized into different ranks, and measures are taken in accordance with these ranks. By doing this, people will no longer be confined entirely in safe areas, but exposed to areas in which a certain degree of danger can be sensed. Their risk management abilities will be fostered, and they will become able to respond to risks in accordance to the "danger ranks".

The second method is for individuals to acquire countermeasures by which they can return alive even if an accident inevitably occurs. We propose the designing of a comprehensive swimming education program as a precautionary measure against such situations. The purpose of swimming education in its early days was neither for health nor record, but the prevention of drowning and the saving of lives. For example, at Harvard University in the United States, 50-yard swimming became mandatory for all students as a result of the loss of a student in the 1912 titanic accident. This training is supposed to allow one to swim back to shore in case of an accident, and the tradition still continues until today. In Japan, Keio University had obligated 50-meter swimming for all students from a similar standpoint. But, as time passed by, swimming education gradually became deflected towards technique training rather than prevention of drowning or saving of lives. The four basic styles of competition swimming are known to cause excessive physical load in in-clothes situations, and swimming styles with less physical burden, such as the elementary backstroke, are important. However, elementary backstroke is not familiar in Japan, and the diffusion of this style is not widespread. In the future, it is necessary to establish a method with elementary backstroke as a central element, to protect oneself from water accidents. Hence, this study compares and contrasts elementary backstroke with the crawl, a typical example of the four styles of competition swimming, in an in-clothes condition in order to investigate the utility of elementary backstroke. The subsequent purpose will be to examine the physiological effects in methods of acquiring elementary backstroke.

METHODS

Details of measurement methods can be found in Fujimoto et al. (2001) [1]. This study was conducted on 24 male members of the Inter-collegiate Swimming Club of Keio University who had no previous experience of the in-clothes swimming. Prior to the training, all subjects were asked to put on a T shirt, a sweat shirt, cotton trousers, socks, and jogging shoes, and underwent the 1st load test consisting of 200-meter swimming with the elementary backstroke, followed by a sufficient break, and finally another 200-meter swimming with the crawl. The subjects were told to perform this in-clothes swimming at a velocity that increases blood lactic acid level to 4 mmol/L after 30 min of swimming (T30)[4,5]. Lap time was recorded for each swimming style and, both prior to and at the completion of each swimming, perceived exertion (the Borg score), heart rate, and blood lactic acid level were determined.

Following the 1st load test, these 24 subjects were divided into 4 groups with 6 each. These four groups were assigned to the in-clothes training (Group A), the image training (Group B), the swimsuit training (Group C), or no training (Group N). Upon grouping the subjects, care was taken that these four groups be not different in body mass index (weight/height), total body surface area, or swimming ability. Values of body mass index, total body surface area, and swimming ability (T30) are summarized in Table 1. After 1st load test, technical aspects of the in-clothes swimming were lectured to Group A, B, and C. The following day, the training initiated. Group A subjects put on a T shirt, a sweat shirt, cotton trousers, socks, and jogging shoes as the load of clothing, and Group C subjects wore a swimsuit. Group B was given the image training formulated according to the non-physical training method described as one type of mental training by Volpert [10]. For one week, Group N practiced no training and was kept in a situation where the subjects were not allowed to image the training. During the training period, Group A, B, and C were engaged also in regular practices. Training sessions were held for Group A and C at the same time and place everyday. At the completion of the one-week training given separately to the 4 groups, the 2^{nd} in-clothes load test was performed. Lap time for 200-meter in-clothes swimming with either the crawl or elementary backstroke, and the Borg score, heart rate, and blood lactic acid were determined both prior to and after 200-meter in-clothes swimming. To help the subject swim the distance in the time required on the 1st load test and experience a similar level of physical load, the lap time of the 1st load test and experience a similar level of physical load, the lap time of the 1st load test was indicated, and the subject were told to achieve the same 25-meter lap. Swimming velocities scored in the 1st and 2nd load test were compared (Table 2). Lap time, heart rate, blood lactic acid, and perceived exertion were all analyzed using Wilcoxon's signed rank test. When the P value was <0.05, the difference was regarded statistically significant.

RESULTS

At the entry to the study, the values of heart rate and blood lactic acid were not different among the subjects. In the 1^{st} load test, no significant difference was observed in 200-meter lap time recorded with the crawl or elementary backstroke among the subjects. Of note, the values of heart rate, blood lactic acid, and the Borg score were all significantly lower for the elementary backstroke than those for the crawl. To verify that the physiological conditions prior to the training session were not different among these four groups, physiological parameters obtained after the 1^{st} load test were statistically evaluated. No difference was found among the four groups, indicating that prior to the training, physiological conditions of these four groups were not distinguishable. Table 4 summarize the values of heart rate, blood lactic acid, and the Borg score determined in the 1st and 2nd load test with the elementary backstroke. For Group N, no significant difference was observed in heart rate, blood lactic acid, or the Borg score between the 1st and 2nd load test. For Group A, B, and C, heart rate and blood lactic acid determined after the in-clothes swimming were both lower for the 2nd load test than those for the 1st load test. These differences were statistically significant, except for blood lactic acid in Group A. Following the training session, the Borg score after the in-clothes swimming was significantly reduced only in Group A.

DISCUSSION

We examined the pre- and post-training values of heart rate, blood lactic acid, and perceived exertion determined after the in-clothes swimming with elementary backstroke. For Group N with no training, no significant difference was observed in any of the physiological parameters between the 1st 2nd load tests. This finding indicates that a single session of the in-clothes swimming does not provide "getting-used-to" effect. Upon the in-clothes swimming, heart rate and blood lactic acid were lower after the 2nd load test for Group A, B, and C than those after the 1st load test. These results suggest that for the elementary backstroke, either the image training or swimsuit training is effective in reducing the physiological load of the in-clothes swimming and, possibly, superior to the in-clothes swimming. Thus, the physical training of the in-clothes swimming is not essential to reduce the physical load. It has been described that the short-term image training alone is equally effective to the physical training, and the best effect is achieved when these two training methods are combined. Twining reported that in acquiring the learning skills through playing quoits, better results were seen with the subjects who practiced physical training after 15 min of mental rehearsal than those who underwent physical training alone [8]. Rawlings et al. described that mental practice by the image training and physical practice by actual exercise were similar in effectiveness in learning the rotary pursuit tracking [6]. In addition, Ulich concluded, from the study on the acquisition of physical abilities requiring skills, that the best learning was achieved when both physical and image training were given [9]. Although different approaches were used, the results of the present study are in agreement with these previous studies and further emphasize the effectiveness and importance of the mental practice. As described above, the elementary backstroke is an instrumental swimming style in reducing the physiological load of the in-clothes swimming. We found that the physiological load and perceived exertion can be further reduced by various kinds of training. While the image training and swimsuit training are similarly effective as the methods of the in-clothes training, the effectiveness may vary depending on the level of the trainee's familiarity with the given swimming style. Image training may be feasible first-step training in hope to prevent the loss of lives in water accidents.

CONCLUSION

We have used physiological indexes to compare the physical load of the crawl and elementary backstroke in an in-clothes condition, assuming the prevention of water accidents. As a result, it has been found that in an in-clothes condition, elementary backstroke causes a lower degree of physiological load. Physiological indexes were also used to examine the effects of elementary backstroke training in in-clothes practice, practice with a swimsuit, and image training. As a result, image training alone was found to have significant physiological effects. Image training is a training method that can be safely conducted by novices, which arouses expectations that this method may be used to provide training even in cases where actual swim training is not possible. In the future, it is important to utilize image training to establish comprehensive training methods that includes training for in-clothes swimming. By establishing such comprehensive swim training, the case fatality rate for water accidents can be expected to decrease. We also hope to propose policies to provide environmental measures to prevent water accidents.

Table 1. Profiles of the Four Training Groups

	In-Clothes Swimming	Image Training	Swimsuit Swimming	No Training
Number	6	6	6	6
Age(years)	19.8±1.3	20.3±1.7	20.8±1.4	20.5±1.9
Body Mass Index (kg/cm)	21.7±1.3	21.6±1.5	22.6±1.2	22.2±1.1
Total Body Surface Area(cm^2)	169.1±11.0	179.5±5.9	176.5±8.4	171.6±7.7
T30(m)*	2,314.2±234.6	2,330.0±174.7	2,319.2±108.7	2,236.7±96.5

*The distancethe subject covered by swimming for 30 min at a velocity that increasesblood lactic acidto 4 mmol/L.

Table 2. Lap time for 200-meter in-clothes swimming before and after the training

		In-Clothes Swimming	Image Training	Swimsuit Swimming	No Training
Crawl	Before	328.2±56.7	296.7±25.0	312.0±58.9	339.5±30.2
	After	325.8±59.2	296.0±22.7	303.7±48.6	340.2±203
Elementary Backstroke	Before	325.3±43.0	291.8±33.9	303.8±61.3	332.0±56.1
	After	324.8±42.4	289.3±28.9	307.0±55.7	333.0±55.4

Both before and after the training session, the subjects performed 200-meter in-clothes swimming with either the crawl or elementary backstroke at a velocity that elevates blood lactic acid to 4mmol/L. The pre-training (Before) and post-training (After) valuesof laptime were compared.

Table 3. Pre-training values of physiological parameters after the first in-clothes load test two swimming styles

	Crawl	Elementary Backstroke
Lap Time	319.1±45.4	313.3±49.3
Heart Rate(beating/min)	162.4±14.2	153.7±15.3
Blood Lactic Acid (mmol/L)	6.5±2.6	4.1±1.9
Borg Score	15.3±1.4	12.5±2.3

*P<0.01 vs. crawl.

Table 4. Pre- and post-training values of physiological parameters determined in 200-meter in-clothes swimming with the elementary backstroke

		In-Clothes Swimming	Image Training	Swimsuit Swimming	No Training
Heart Rate (beating/min)	Before	147.2±13.0	158.5±16.3	159.3±9.4	149.7±20.5
	After	133.3±17.1*	140.5±19.4*	144.7±16.5*	141.2±23.0
Blood lactic acid (mmol/L)	Before	3.6±1.8	4.6±1.6	4.3±1.8	4.1±2.6
	After	3.0±1.4	3.7±1.7*	3.3±1.4*	4.0±2.3
Borg Score	Before	13±2	13±4	12±1	12±3
	After	12±2*	11±1	12±1	13±2

Both before and after the training session, the subjects performed200-meter in-clothes swimming with the crawl. Heart rate, blood
lactic acid, and Borg score were determined, andthe pre-training(Before) and post-training(After) values were compared.

*P<0.05 between the pre- and post-trainingvalues.

REFERENCES

1. Fujimoto H. Inokuchi S. Ishida H (2001). Effects of physical training and mental practice of in-clothes swimming: Assessment by physiological parameters. The TokaiJournalof Experimental and Clinical Medicine 26(4-6):139-145.

2. Kanagawa Lifesaving Association (1993). Survival Swimming. 4-5.

3. NationalPolice Agency (2004). Police White Paper.

4. Olbrecht J, Madsen A, Liesen A, and Hollman W (1985). Relationship between swimming velocity and lactic acid concentration during continuous intermittent training exercise. InternationalJournalof Sports Medicine 6:74-77.

5. Olbrecht J, Marder A, Heck H, Hollman W (1988). Relation between lactate and swimming speed depending on the test conditions; pool length, before and after endurance training, AM versus PM, qualifications and finals, and relay or

individual races. (Abstract) International Journal of Sports Medicine 9: 379.
6. Rawlings E. Rawlings IL. Chem SS. Yilk MD (1972). The facilitating effects of mental rehearsal in the acquisition of rotary pursuit tracking. Psychonomic Science 26:71-73.
7. Riverfront Equipment Foundation (1992). Familiarity with rivers and prevention of accidents by water: In-clothes swimming for water safety. 119-121.
8. Twining WH (1949). Mental practice and physical practice in learning a motor skill. Research Quarterly 20:432-435.
9. Ulich E (1967). Some experiments on the mental training in the acquisition of motor skills. Ergonomics 10: 411-419.
10. Volpert W (1973). Sensumotorisches Lernen. Limpret, Frankfurt.

The dolphin assisted activity effects relaxation and healing

Hideki Hara[1], Katuyuki Goto[2], Miki Iwayoshi[2], Hiroya Negishi[2], Megumi Watarai[2], Noriko Yokoyama[2], Sachie Sugiyama[2], Lena Akai[3], Ikuo Homma[3]

[1] Kokugakuin University, Faculty of letters, Japan

[2] NPO Experience Activity Meeting for the Study, Japan

[3] Showa University, Department of Physiology, Japan

We have been practicing dolphin assisted programs since 1998 in Ito City, Shizuoka Prefecture, JAPAN. Our first purpose is to explore the positive effects of such experiences in nature on children especially in sea side location. The second purpose is to offer relaxation and healing through interaction with dolphins. This facility has a pen in ocean surrounded by wooden platform decks. Guests can touch or feed fish to the dolphins from the deck. With good weather conditions, guests can also swim with the dolphins under close supervision by the dolphin trainers. These programs are open for anyone. In 2007, 1797 guests visited the dolphin interaction program and 2362 guests came to swim with the dolphins. We held special camps for physical and/or mentally handicapped persons, including autistic individuals and their families and children with depression. We had three seminars to present our findings and to offer information on dolphin assisted activity programs.

Key words: *dolphin assisted, interaction, relaxation, healing, seaside*

INTRADUCTION

In natural environments, people living in city area, feel something relaxed without any special activities or treatments. We are refreshed with air, sunshine, wind and fragrance in forest, hills and seaside area. River, lake and ocean relieve the work time tension of us. Effects of water immersion are happened to increase venous return and to make autonomic nervous system change from high tension (3) . Those are generally known that having a shower or bath, and swimming and scuba diving are not only psychologically but also physiologically effective for human. From the other report, exercise in water effect on autistic children (6) . Further, animal assisted activities might be effective for mentally disordered conditions (2, 4, 5) . In Japan, dolphin assisted activities and dolphin assisted therapy are practiced in Okinawa, Kii peninsula and some other places (7) . Because of those activities are usually opened in only summer time, people are not enjoyed so many times in Japan. Compared with those cases, our dolphin assisted activities are open through all seasons in Ito city, Izu peninsula of Shizuoka prefecture, and this is the characteristics of our facilities that guests can swim with dolphins in good weather and dolphin's condition. We started for children having enjoyable experiments in seaside nature and to offer relaxation and healing through interaction with dolphins.

METHODS

1) Facilities

" Dolphin Fantasy" is the name of our facility. There is a two-story beach house for guest and scuba divers named Ito Diving Service at the south part of Ito-bay, in Izu peninsula, Shizuoka prefecture. In the short distance from the beach house, there is a wooden pen tighten to the pier by the rope. The size is about 30m long and 20m width, flouting in ocean and net attached to the bottom of ocean. Our staff and Guests are going to the pen for interaction by the wooden float pulling with rope apart from a pier.

Figure 1. The scene from the beach house. (Left) There is the pen in which interactions,

such as feeding, touching and swimming are performed and the flout using for across from a pier to the pen. A flout (Right) using for go and return from a pier to the pen with drawing ropes for interaction with dolphins.

2) The general programs and the nursing school program

The general programs are open four times a day except in bad weather and/or dolphin condition. Two of them are in the morning and two in the afternoon. In general program, guests are receipted at the beach house. The nursing school students, who were affected by child abuse from their parents, were using one of those general programs. Guests and students have some lectures about ecology and physiology of dolphin. The dolphin trainer explained how to feed fish and touch and swim with three female dolphins. Guests are wearing life best and long boots till one's breast in case of only feeding and touching from the pen. In case of swimming with dolphin, they are wearing wet suite or dry suite and diving mask, snorkel, fins and globes while performing interaction with dolphins. In both interactions, everyone experiences that dolphin eyeing us thoughtfully from water. Guests and students are enjoying swimming with her, approaching slowly and reaching toward guests' hands with her flipper and body. They are swimming or diving around gently.


Figure 2. A guest children feeds fish for a dolphin from his hand (Left). And a guest, a dolphin trainer and a volunteer are swimming with a dolphin in the camp. (Right)

3) The Special camp programs

The special camp programs are opened for physically and/or mentally handicapped persons, including autistic individuals and their families. This type of program is a three-day camp and also preparing for families. Hotels are accepted for barrier free rooms and meal. In these special camps, not only dolphin trainers but pediatricians, nurses, and clinical psychologists along with numerous volunteers, who are diving instructors and college students and so on. The first day, after reception, attendants are going to the dolphin fantasy and accustom to unusual surroundings such as beach house and seaside locations. They have a short lecture and move to a pier, and some are crossing to the pen and feeding fish to dolphin or touching with her. The second day, they are going to the dolphin fantasy again to attend swimming or exchanging programs and also going to beach to enjoy sea side attractions for relaxing or healing. On the third day, attendants are exchanging with dolphins again.

RESULTS AND DISCUSSION

1) The general program

For our general programs in 2007, 4159 guests visited the dolphin interaction programs and 2362 of them were attended to swim with dolphins. Especially in summer season, guests enjoyed dolphin swimming programs and felt unusual relaxation and healing even in thirty minutes. Almost all the attendants mentioned that they could not stop smiling with dolphin behavior and felt relaxation and healing.

2) School programs

This program started since 2000. Those students were neglected by their parents or families and others had not adopted for the general school life and had not presented for classes. So they were living dormitory and going to nursery school. Those programs were opened for about once in a month through a year so totally opened sixty times. Students knew much more things about dolphin and became strong friendships with dolphin. Furthermore, they changed to estimate themselves adequately, and attempt to communicate with dolphin trainers, friends and teachers and accepted others. Their expression changed to gentle and friendly in daily life.

3) Special camp programs

One type of special camps for handicapped persons held six times in 2006 and 2007. The symptoms and diseases were as follows: learning disorder, attention deficit hyperactivity disorder, epilepsy, panic disorder, autism, Down's syndrome, cerebral palsy, hydrocephalus, spinal injury, visual impairment, hearing impairment, coxarthrosis, atopic dermatitis, noonan's syndrome. The attendants for special programs felt tender-hearted eyesight from dolphins and refreshment from environment. Those feelings were also due to many volunteers who helped in hotels and seaside area showing in Table 1.

Table 1. The numbers of attendance for those special programs

		families	patients	total	volunteers
1	2006/8/1	19	19	59	11
2	2006/9/1	21	21	64	21
3	2007/3/1	10	10	36	12
4	2007/8/1	10	10	35	27
5	2007/9/1	10	11	37	12
6	2007/10/1	14	14	45	18
	Total	84	85	276	101

The other type of special camp had begun in 1999 once a year for children to have experience in seaside location. More than one thousand and eight hundreds of children with and without disabilities gathered and more than five hundreds of volunteers assisted their activities during nine years. This type of camp was one or two day session. So attendants exchanged with dolphins once or twice in short periods. Even though it was a short time, they have been fascinated with dolphin.

4) Seminars

We also had seminars once a year to present our findings and to offer information on dolphin assisted activity programs to those kinds of patient's families and other people who knew those seminars by the web site of the dolphin fantasy since 2005.

CONCLUSION

We presented dolphin assisted activities since 1999. Thousands of people, with and without physically or mentally handicapped, enjoyed exchanging programs and relieve high tension of daily lives. Some of autistic children came to look mild face and were able to take more communications friendly or take more eye contacts than before experienced those dolphin assisted programs. Because we felt that not only a questioner method but also a physiological evidence were needed for those changing of attendants, so we have started to explore the effect of touching a dolphin on respiration and brain activity (1). (Figure 3)

Figure 3. The experiment on physiological responses in respiration and brain activities before and after the dolphin touching program.

Acknowledgements

Those programs are supported by the government of Shizuoka prefecture and Ito city, and by Japan Welfare Children and Families Association and Japan Barrier Free Diving Association and NPO association of Experience Activity Meeting for the Study.

REFERENCES.

1. Homma A, Hara H, Matsuzaki K, Nakagawa Y, Masaoka Y, Homma I. (2008). The effect of touching a dolphin on respiration and brain activity in children. Int J Healing and Caring. Vol.8. No.1.
2. Nathason DE, Faria S. (1993). Cognitive improvement of children in water with and without dolphins. Anthrozoos, Vol.6, No.1, 17-29.
3. Nishimura M, Onodera, S. (2000). Relaxation effects of supine flouting on heart rate, blood pressure and cardiac autonomic nervous system activity. J J Aerospace Env Med, 37, 49-56.
4. Smith, BA. (1988). The autistic person experiences Atlantic bottlenose dolphin as therapy. Nat Aquatic J, 4, 5-6.
5. Smith, BA. (1996). Dolphin assisted therapy. Tokyo:Koudansha.
6. Sugi K, Matsuda S, Onodera S, Sanada S, Nakashima Y, Sasaki M, Egusa Y. (2002) The effect of water exercise on behavior and language of children with autism. Kawasaki Medical Welfare journal Vol.12, No.1, 133-137.
7. Tsujii M, Nakamura K. (2003). Introduction of dolphin therapy. Tokyo: Brain shuppan.

Comparison of two-year effects of once-weekly and twice-weekly water exercise on activities of daily living (ADL) disability of community-dwelling frail elderly

Daisuke Sato[1], Koichi Kaneda[1], Hitoshi Wakabayashi[2], Takeo Nomura[1]

[1] Doctoral Program in Comprehensive Human Science, University of Tsukuba, Japan

[2] Faculty of Design, Kyushu University, Japan

Previous researches suggest that a water exercise improve Activities of Daily Living (ADL) disability and lower extremity muscle strength of frail elderly, but the specific frequency and intensity of such programs is unclear. This study was aimed to compare the two-year effects of once- and twice-weekly water exercise on ADL disability of frail elderly receiving a low level of nursing-care. Once- and twice-weekly water exercise interventions for six months at a day service facility improve ADL disability. Once- and twice-weekly water exercise had the effect of sustaining ADL disability for toilet transfer, bathing transfer and stair climbing achieved after a six-month water exercise period in the frail elderly receiving nursing care for one year. The two-year water exercise program, conducted twice a week in a day service facility, was effective for maintaining ADL disability for transfer, bathing transfer, mobility (locomotion) and stair climbing.

Key words: water exercise, frail elderly, activities of daily living disability

Introduction

Several studies have shown that regular exercise is beneficial to improve the ADL disability of frail elderly. Especially, frail elderly benefit from exercise because of their low level of functioning attributable to their inactive lifestyle [1]. Although exercise imparts positive effects on physical and mental health, physical activity increases opportunities for falling: the perceived risk of falling is a widely recognized barrier to exercise [2].

Water is a low-risk exercise environment that might reduce acute injury and fear of falling [3]. Although previous studies have indicated that water exercise more than twice a week improved ADL disability [4, 5], few studies have investigated effects of once-weekly water exercise on them. Low-frequency and low-intensity exercise programs have higher adherence and are more acceptable for frail elderly [1]. Therefore, it is necessary to clarify the effects of water exercise according exercise frequency.

For exercise frequency, more than twice-weekly exercise had larger effect on functioning of elderly than once-weekly [6]. Frail elderly are more likely to deteriorate ADL disability than non-frail older people [7]. Therefore, ADL disability changes might differ according to exercise frequency and once-weekly water exercise might be less sufficient to maintain them achieved after short-term water exercise.

This study is aimed to compare the two-year effects of once- and twice-weekly water exercise on ADL disability of frail elderly receiving a low level of nursing-care.

Methods

Participants

Through informational talks, frail elderly participants who were currently receiving nursing-care and who used the Day Service available within the Japanese public nursing care insurance system (PINCIS) were recruited for the study. All participants were randomly assigned to either the once-weekly or twice-weekly intervention group (Group 1 or Group 2). Group assignments were carried out by the nursing care manager, who was unrelated to this intervention study.

Intervention

All participants used the day service. Groups 1 and 2 participated in the water exercise for one hour once weekly and twice weekly, respectively. The pool had a water depth of 1.05–1.15 m, water temperature of 33°C, and ambient temperature of 30°C. Exercise sessions were divided into a 10-minute warm-up consisting of flexibility exercise on land and 50 minutes of exercise in water. The 50-minute water exercise program consisted of 10 minutes of walking, 20 minutes of ADL exercise, 10 minutes of stretching and strengthening, and 10 minutes of relaxation in water. Participants performed functional mobility in the water. Exercise intensities of both programs were set at 11 on a rating of perceived exertion scale (RPE) [8].

Measurement

ADL disability and lower extremity muscle strength were measured before starting the exercise program (pre) and subsequently six months (6-month), one year (1-year), and two years (2-year) after the beginning of the program.

The functional independence measure (FIM) was used to assess ADL disability [9]. A clinical nurse working full-time at the day service facility evaluated ADL disability using the FIM. Each item is scored using a scale of 1-7 points. A higher score indicates lower ADL disability. In this study, ADL disability scores on transfer (to chair and bed), bathing transfer, toilet transfer, mobility (locomotion), and stair climbing were evaluated. ADL disability with respect to functional mobility was shown by the total score of these five items.

Knee extensor muscle strength (KEX) and ankle dorsiflexor muscle strength (ADX) were measured at Bohannon's position using a hand-held dynamometer (LP-100KB; Kyowa Giken Co. Ltd.) [10]. Two trials were administered for each test on each limb. The averaged higher value for each leg was used for analysis.

Result and Discussion

In this study, we compared the two-year effects on the ADL disability of frail elderly people of once-weekly and twice-weekly water exercise at a day-service facility. This is the first longitudinal study to investigate the effects of water exercise on the ADL disability of frail elderly people.

Table 1 shows the FIM scores and KEX value at pre, 6-month, 1-year and 2-year during the exercise program. Once- and twice-weekly water exercise during a six month period improved ADL disability for functional mobility and KEX. The results of this study indicated that increases in KEX and water exercise programs that include ADL exercise seem to have beneficial effects on the improvement of ADL disability for functional mobility.

However, only twice-weekly water exercise maintained ADL disability from the 6-month to 2-year measurement periods. In particular, significant differences between once- and twice-weekly water exercise were found only at the 2-year measurement in ADL disability for bathing transfer and stair climbing. In addition, a significant difference in KEX at the 2-year measurement was not seen between the two groups, although the effect size was moderate from the 1-year to 2-year measurement periods. It has been reported that the amount of deterioration in ADL disability differs depending on the activity: a significant initial deterioration in ADL disability has been

Table 1. the FIM scores and KEX at pre, 6-month, 1-year and 2-year

	Group 1 (n =9)		Group 2 (n =11)	
Functional mobility (points)				
pre	28.1 ± 1.8		26.6 ± 2.1	
6-month	31.9 ± 2.3	*	32.9 ± 2.4	*
1-year	31.9 ± 2.3	*	33.1 ± 2.4	*
2-year	30.4 ± 2.2		32.6 ± 2.7	*
Transfer (to chair and bed, points)				
pre	5.9 ± 0.3		5.4 ± 1.0	
6-month	6.4 ± 0.5		6.7 ± 0.5	*
1-year	6.4 ± 0.5		6.7 ± 0.5	*
2-year	6.3 ± 0.5		6.6 ± 0.5	*
Toilet Transfer (points)				
pre	5.7 ± 0.5		5.7 ± 0.9	
6-month	6.4 ± 0.5	*	6.8 ± 0.5	*
1-year	6.4 ± 0.5	*	6.8 ± 0.5	*
2-year	6.3 ± 0.5		6.6 ± 0.5	
Bathing Transfer (points)				
pre	5.8 ± 0.4		5.4 ± 1.0	
6-month	6.4 ± 0.5	*	6.8 ± 0.5	*
1-year	6.4 ± 0.5	*	6.8 ± 0.5	*
2-year	6.0 ± 0.0		6.6 ± 0.5	*†
Mobility (locomotion, points)				
pre	6.1 ± 0.7		5.6 ± 0.9	
6-month	6.6 ± 0.5		6.7 ± 0.5	*
1-year	6.6 ± 0.5		6.8 ± 0.5	*
2-year	6.3 ± 0.5		6.6 ± 0.5	*
Stair Climbing (points)				
pre	4.6 ± 1.0		4.5 ± 1.4	
6-month	6.1 ± 0.6	*	6.1 ± 0.8	*
1-year	6.1 ± 0.6	*	6.2 ± 0.8	*
2-year	5.6 ± 0.8		6.2 ± 0.8	*†
KEX (kg/weight)				
pre	0.14 ± 0.05		0.21 ± 0.08	
6-month	0.26 ± 0.11	*	0.31 ± 0.11	*
1-year	0.30 ± 0.12	*	0.30 ± 0.11	*
2-year	0.25 ± 0.05		0.30 ± 0.11	*

NOTE.. Values are mean±SD.
*:Significant difference compared to baseline value ($p<0.05$)
†:Significant difference between two groups ($p<0.05$)

observed for bathing transfer and stair climbing among the frail elderly [11]. Further, bathing transfer and stair climbing seem to require higher KEX than other activities [11]. This is one reason why the present results indicated that KEX affected ADL disability for bathing transfer and stair climbing. Indeed, exercises for maintaining ADL disability for bathing transfer and stair climbing are reportedly the most difficult during rehabilitation [11]. Nishiwaki et al. [12] have suggested that a more efficient approach for maintaining ADL disability is to offer exercises targeted at specific activity limitations. Therefore, we can conclude that twice-weekly water exercise, which maintained ADL disability for bath transfer and stair climbing from the 6-month to 2-year measurements in our study, is useful for rehabilitation of the frail elderly.

Conclusion

Once- and twice-weekly water exercise had the effect of sustaining ADL disability for toilet transfer, bathing transfer and stair climbing, as well as KEX values achieved after a six-month water exercise period in the frail elderly receiving nursing care for one year. The two-year water exercise program, conducted twice a week in a day service facility, was effective for maintaining ADL disability for transfer, bathing transfer, mobility (locomotion) and stair climbing.

Reference

1. Chin A, Paw MJM, van Poppel MNM, Twisk JWR, van Mechelen W. (2006). Once a week not sufficient, twice a week not feasible? Patient Edu Counsel, 63:205-14.

2. Hauer K, Specht N, Schuler M, Bartsch P, Oster P. (2002). Intensive physical training in geriatric patients after severe falls and hip surgery. Age Ageing, 31:49-57.

3. Forwood MR, Larsen JA. (2000). Exercise recommendations for osteoporosis. A position statement of the Australian and New Zealand Bone Mineral Society. Australian Family Physician, 29:761-4.

4. Devereux K, Robertson D, Briffa NK. (2005). Effects of a water-based program on women 65 years and over: A randomised controlled trial. Australian J Physiotherapy, 51:102-8.

5. Foley A, Halbert J, Hewitt T, Crotty M. (2003). Does hydrotherapy improve strength and physical function in patients with osteoarthritis – a randomized controlled trial comparing a gym based and a hydrotherapy based strengthening programme. Ann Rheum Des, 62:1162-7.

6. Demichele LP, Pollock LM, Graves EJ, Foster ND, Carpenter D, Garzarella L, Brechue W, Fulton M. (1997). Isometric torso rotation strength, Effect of training frequency on its development. Arch Phys Med Rehabil, 78:64-69.

7. Katz S, Branch LG, Branson MH. (1983). Active life expectancy. N Engl J Med, 309:1218.

8. Onodera K, Miyashita M. (1976). A study on Japanese scale for rating of perceived exertion in endurance exercise. Jap J Phys Edu, 21(4):191-203.

9. Granger CV, Hamilton BB, Keith RA. (1986). Advance in functional assessment for medical rehabilitation. Top Geri Rehabil, 1:59-74.

10. Bohannon RW. (1986). Test-retest reliability of hand-held dynamometry during single session of strength assessment. Phys Ther, 66:206.

11. Sato S, Demura S, Kobayashi H, Nagasawa Y. (2002). The relationship and its change with aging between ADL and daily life satisfaction characteristics in independent Japanese elderly living at home. J Phys Anth Appl Human Sci, 21(4): 195-204.

12. Nishiwaki T, Nakamura K, Ueno K, Fujino K, Yamamoto M. (2005). Health characteristics of elderly Japanese requiring care at home. Tohoku J Exp Med, 205: 231-9.

Suggestion of "NEW" application of deep-water running in the elderly

Koichi KANEDA[1], Daisuke SATO[1], Hitoshi WAKABAYASHI[2], Atsuko HANAI[3], Tamotsu UEKUSA[4], Takeo NOMURA[1]

[1] Graduate School of Comprehensive Human Science, University of Tsukuba, Japan

[2] Graduate School of Design, Kyushu University, Japan

[3] Sports Science Program, Department of Liberal Studies, Hokusho college, Japan

[4] Uekusa Gakuen Junior College, Chiba, Japan

We have measured muscles activity of deep-water running (DWR) by comparing with land walking and water walking, and cleared that DWR used thigh and trunk muscles for postural controlling during unstable upright floating situation. From that, it was hypothesized that DWR has effectiveness of balance training for elderly. This study aimed to suggest "NEW" application of DWR in the elderly. Thirty healthy elderly men and women were assigned to a deep-water running exercise group or a normal water exercise group. They completed a twice-weekly water exercise intervention for 12 weeks. Another fourteen elderly men and women completed a once-weekly intervention for 12 weeks. The tandem walk time was significantly decreased in DWRE group both once- and twice-weekly water exercise intervention. It was suggested that DWR was a exercise sufficient for improving not only an aerobic fitness but also a dynamic balance ability in elderly people regardless of exercise frequency.

Key words: *Balance, Postural control, Floating, Thigh and trunk muscles.*

INTRODUCTION

Deep-water running (DWR) is a typical form of water exercise because a person can float vertically with a floating device. Advantages of DWR include reduction of the vertical component stress for lower limb joints and maintaining aerobic fitness[6]. We, in the past, have measured lower extremity and trunk muscles activity during DWR comparing with land walking (LW) and water walking (WW) in young adults. The study cleared that the DWR has characteristics of stimulating the hip joint muscles especially in the hip extensors, hip adductors and abductors more than LW and WW, and the obliquus externus abdominis (OEA) more than WW with greater hip joint range of motion and trunk forward inclination. Water environment has a low risk of falling and the consequent lack of fear of falling during exercise[2]. For that reason, the investigation of the effects in the elderly people has a benefit to suggest of "NEW" application of DWR. Winter[9] noted that the stability of the upper body might be beneficial for balance control. He also described how the hip adductor and abductor muscles dominate balance control in the medio-lateral direction. The elderly use thigh muscles activity more often than young adults during balance control[1]. From these previous studies, it was hypothesized that DWR is more beneficial for the maintenance of balance ability especially in the elderly. This study was designed to investigate the effects of water exercise, which included DWR in comparison to normal water exercise which mainly consisted of water-walking, for the purpose of suggesting "NEW" application of DWR.

METHODS

Subjects. Thirty community-dwelling elderly volunteers (60.7 ± 4.1 yr) were recruited to a twice-weekly, and another fourteen elderly volunteers (60.8 ± 5.3 yr) were recruited to a once-weekly, 12 weeks water exercise intervention. The subjects were assigned to a normal water exercise (NWE) group or a deep-water running exercise (DWRE) group based on pre-performance test data with no differences between the two groups. All subjects have no problems such as orthopedic diseases of the lower extremities. The subjects were instructed not to change their usual lifestyle during the study.

Exercise Protocol. Exercise sessions were divided into a 10-min warm-up on land, a 20-min water-walking exercise, a 30-min water exercise either NWE or DWRE group, a 10-min rest on land, and a 10-min recreation and relaxation in water. NWE participants performed forward walking, backward walking, side walking, kicking, knee up, twisting, and other water-walking exercises. DWRE participants performed running exercises without their feet touching the bottom of the pool using a flotation device[6]. The water depth of 1.1–1.3 m and the water temperature was 30°C.

Outcome Measurements. The postural sway test was conducted using a posturographic meter (Gravicoda GS-10, type-C; Anima Co., Tokyo, Japan). Tests were conducted for 30 s with eyes open, and postural sway density was analyzed. Postural sway tests are often used to measure static balance ability[3]. Tandem-walking tests were conducted. Subjects were required to walk heel-to-toe along a 10-step line as quickly as possible without misstepping. The times of the two trials without misstepping were then averaged. The tandem-walking test is often used as a measure of dynamic balance ability[7]. For normal and maximal walking tests, subjects walked along an 11-m walkway without walking aids. During the first and second trials, the subjects were asked to walk at a self-selected comfortable speed as the normal trial. During the third and fourth trials, they were asked to walk as fast as possible without running as the maximal trial. The time from 3 m to 8 m was measured at the subject's waist, and the walking speeds were calculated. The calculated speeds of the two trials were then averaged. Walking speed is often used to assess the total fitness level of elderly people[4].

RESULTS

In the twice-weekly intervention, the tandem walk time was significantly decreased in DWRE group (14.1%, p < 0.05, Table 1). In the case of once-weekly, the tandem walk time was significantly decreased in DWRE group (10.8%, p < 0.05, Table 2).

Table 1. Values of each performance test at pre and post 12-week water exercise (A twice-weekly).

	Pre		Post		Two-way ANOVA group × time effect
	NWE (*n* = 15)	DWRE (*n* = 15)	NWE (*n* = 15)	DWRE (*n* = 15)	p-value
Postural sway density (cm/cm^2)	24.71 ± 13.07	23.49 ± 7.43	26.08 ± 10.51	24.33 ± 13.13	0.89
Tandem walking time (s)	7.8 ± 1.3	7.8 ± 2.1	7.3 ± 1.4	6.7 ± 1.2 *	-
11 m noraml walking speed (m/s)	1.43 ± 0.14	1.38 ± 0.16	1.44 ± 0.18	1.40 ± 0.17	0.97
11 m maximal walking speed (m/s)	1.93 ± 0.15	2.00 ± 0.19	1.99 ± 0.20	2.07 ± 0.30	0.42

Values are mean ± SD.

*: significant difference between pre and post test, $p < 0.05$

NWE: normal water exercise group

DWRE: deep-water running exercise group

Table 2. Values of each performance test at pre and post 12-week water exercise (A once-weekly).

	Pre		Post		Two-way ANOVA group × time effect
	NWE (n = 7)	DWRE (n = 7)	NWE (n = 7)	DWRE (n = 7)	p-value
Postural sway density (cm/cm^2)	23.50 ± 11.84	18.74 ± 7.94	24.26 ± 11.20	20.51 ± 7.14	0.75
Tandem walking time (s)	7.3 ± 1.4	7.4 ± 1.1	6.9 ± 1.1	6.6 ± 0.8 *	0.64
11 m noraml walking speed (m/s)	1.34 ± 0.26	1.52 ± 0.25	1.51 ± 0.12	1.40 ± 0.14	0.06
11 m maximal walking speed (m/s)	2.03 ± 0.19	2.05 ± 0.19	2.19 ± 0.05	2.17 ± 0.24	-

Values are mean ± SD.

*: significant difference between pre and post test, $p < 0.05$

NWE: normal water exercise group

DWRE: deep-water running exercise group

DISCUSSION

In the elderly, hip flexion and extension, adduction and abduction, trunk muscles are more important than young adults in a balance controlling[1,9]. It was considered that the stimulation to those muscles during DWR that were cleared by our EMG experiments would affect to decrease the tandem-walking time in DWRE group, which indicates improvement in dynamic balance ability[7]. However, there was no change in the postural sway density, which might be affected by water wave or turbulence created in water exericse activity[8]. Simmons et al.[8] reported the improvement of functional reach test by water exercise in the elderly described that water environment reduce weight bearing and provide movement error during exercise because of water buoyancy and resistance. In the previous studies, which investigated the effects of a third-weekly land exercise intervention, reported the improvement of tandem walking test in 23.3%[7] for 6 month or 33.8%[5] for 12 month. In the present study, the improvements of tandem walking test were 14.1% in a twice-weekly and 10.8% in a once-weekly intervention for 12 weeks. It was considered that the DWR was a sufficient exercise for improving tandem walking test in the elderly.

CONCLUSION

As a "NEW" application of DWR, it was suggested that DWR was a sufficient exercise for improving not only an aerobic fitness but also a dynamic balance ability in elderly, and it could gain the effects regardless of exercise frequency.

REFERENCES

1. Amiridis IG, Hatzitaki V, Arabatzi F. (2003). Age-induced modifications of static postural control in humans. Neurosci Lett, 350: 137-40.

2. Devereux K, Robertson D, Briffa NK. (2005). Effects of a water-based program on

women 65 years and over: A randomized controlled trial. Australian Journal of Physiotherapy, 51:102-8.

3. Fujita T, Nakamura S, Ohue M, Fujii Y, Miyauchi A, Takagi Y, Tsugeno H. (2005). Effect of age on body sway assessed by computerized posturography. J Bone Miner Metab, 23: 152-156.
4. Judge JO, Underwood M, Gennosa T. (1993). Exercise to improve gait velocity in older persons. Arch Phys Med Rehabil, 74: 400-406.
5. Nelson ME, Layne JE, Bernstein MJ, Nuernberger A, Castaneda C, Kaliton D, Hausdorff J, Judge JO, Buchner DM, Roubenoff R, Fiatarone SMA. (2004). The effects of multidimensional home-based exercise on functional performance in elderly people. J Gerontol Biol Sci Med Sci, 59: M154-60.
6. Reilly T, Dowzer CN, Cable NT. (2003). The physiology of deep-water running. J Sports Sci, 21: 959-72.
7. Rooks DS, Kiel DP, Parsons C, Hayes WC. (1997). Self-paced resistance training and walking exercise in community-dwelling older adults: effects on neuromotor performance. J Gerontol Biol Sci Med Sci, 52: M161-8.
8. Simmons V, Hansen PD. (1996). Effectiveness of water exercise on postural mobility in the well elderly: an experimental study on balance enhancement. J Gerontol Biol Sci Med Sci, 51: M233-8.
9. Winter DA. (1995). Human balance and posture control during standing and walking. Gait Posture, 3: 193-214.

Effects of water exercise on blood pressure at elderly subjects

Takaaki Aoba[1], Atsuko Hanai[2] and Takeo Nomura[3]

[1] Faculty of Physical Education, Kokushikan University, Japan

[2] Department of Liberal Studies, Hokusho University, Japan

[3] Graduate School of Comprehensive Human Science, University of Tsukuba, Japan

The purpose of this study was to observe longitudinal effect of the short term water exercise program on blood pressure in elderly. Hundred subjects were participated the 8 week water exercise program for 90 minutes twice a week. Blood pressures (SBP and DBP) were measured before and after the water exercise program. Resting blood pressure and the habitual exercise from 5 months to 5 years after finishing water exercise program period were assessed at follow-up measurements. In the follow-up the improvement of blood pressure was shown in the subjects who finished the water exercise program period and had passed within a year. From these results, it was suggested that the short term water exercise program for 8 weeks will be able to decrease blood pressure and also motivate for exercise habitation to maintain and improve their blood pressure.

Key words: *water exercise, elderly subject, systolic blood pressure, diastolic blood pressure, classification of hypertension, recognition for health*

INTRODUCTION

In the previous studies, it was reported that water exercise will improved a life-style related to disease in many elderly. An exercise and it's follow-up is important, because the effect was lost and return to the baseline after stopped exercise for 3 months. The purpose of this study was to observe longitudinal effect of the short term water exercise program for 8 weeks on blood pressure in elderly.

METHODS

The number of the subjects were 100 elderly (water exercise group), mean age was 59.1±10.0 yrs.. The number of control group were 30 elderly (13 female and 17 male), mean age was 57.0±12.5 yrs.

After finishing water exercise program period, 50 elderly (35 female and 15 male) also participated the follow-up studies. Their mean ages were 60.5±9.8 yrs. These subjects were divided into 5 groups, 1) 5M group (within 5 months had passed after finishing water exercise program period, n=13), 2) 1Y group (from 5 months to a year, n=12), 3) 2&3Y group (from a year to 2 or 3 years, n=12, 4) 4&5Y group (from 3 years to 40 or 5 years, n=13).

The exercise program was consisted of warm-up on land, walking, strengthening & stretching, aerobic exercise and relaxation & cool down in water for 90 minutes twice a week for 8 weeks (Figure 1). Blood pressure (Systolic Blood Pressure; SBP and Diastolic Blood Pressure; DBP) were measured before and after the water exercise program used by a wrist automatic sphygmomanometer (Matsushita co. Japan). The measurements were taken 3 times and the data were averaged.

Moreover, the follow-up measurement for resting blood pressure and the habitual exercise from 5 months to 5 years after finishing water exercise program period were also assessed. The data were analyzed by one-way ANOVA.

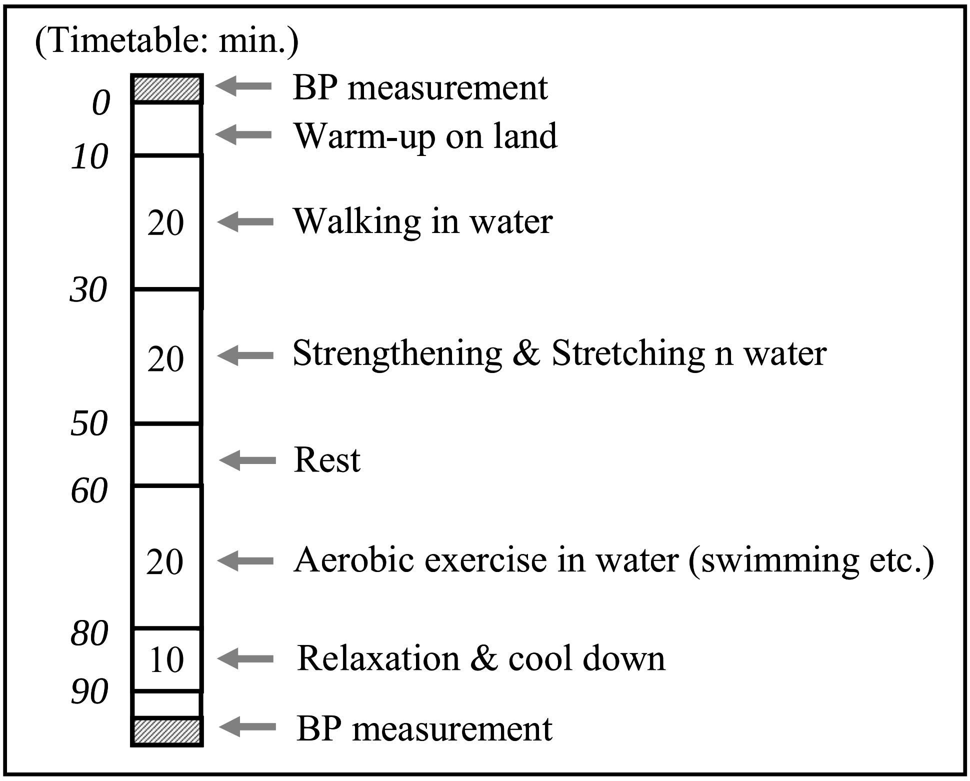


Figure 1. Protocol of water exercise program.

Figure 2. Picture of water exercise program for elderly subjects.

RESULTS

Blood pressure was improvement the water exercise at 8 weeks ($p<0.001$, Figure 3). In the elderly subjects, a significant improvement of SBP or DBP was shown among the subjects in elder group (Figure 4) and high blood pressure level (classification of hypertension level; WHO/ISH, 1999, Figure 5).

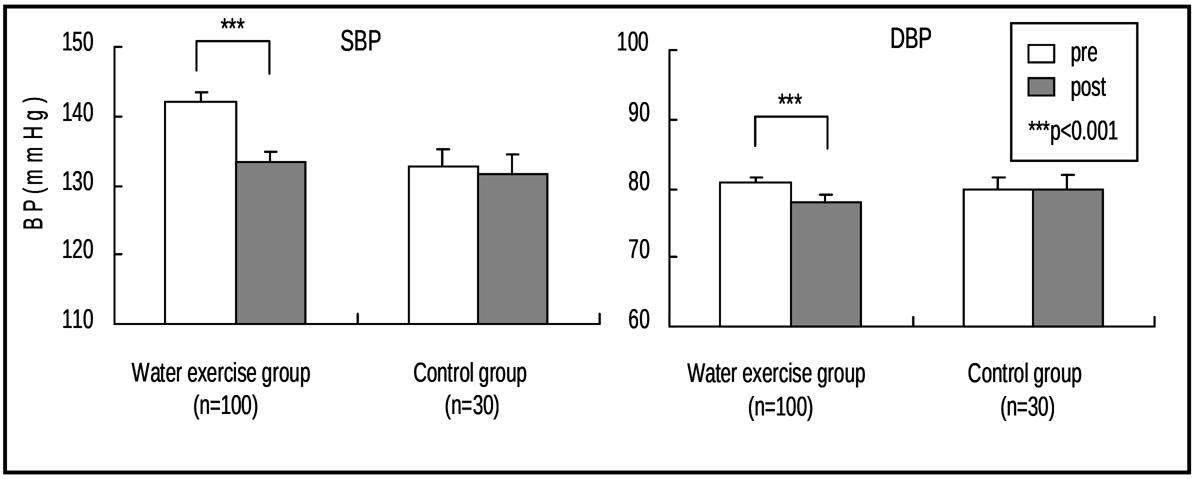


Figure 3. Comparison of BP in water exercise group and control group at water exercise period (mean±SE).

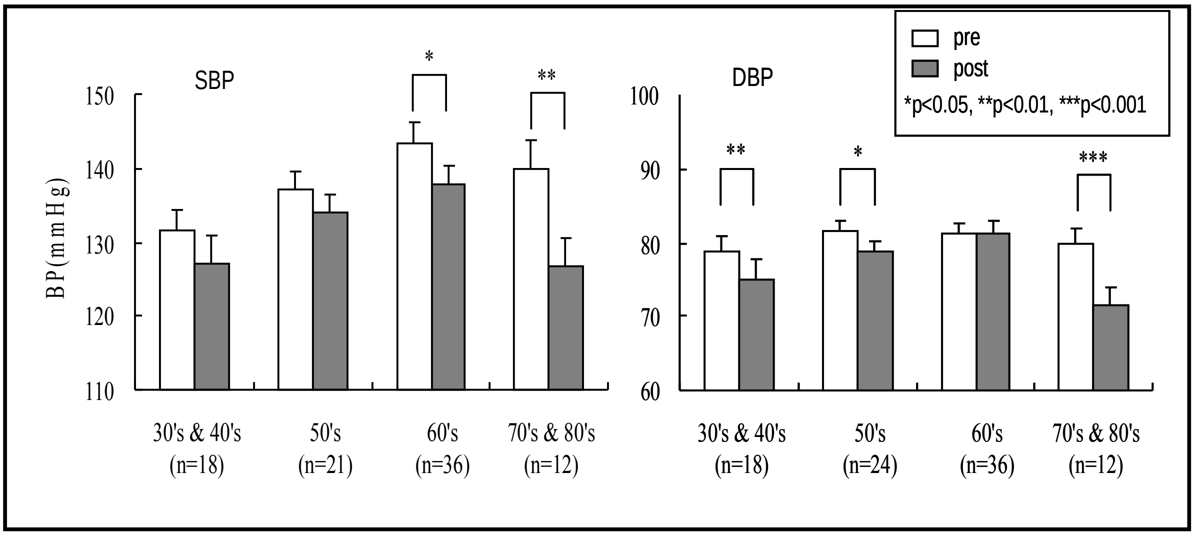


Figure 4. Comparison of BP between age groups (mean±SE).

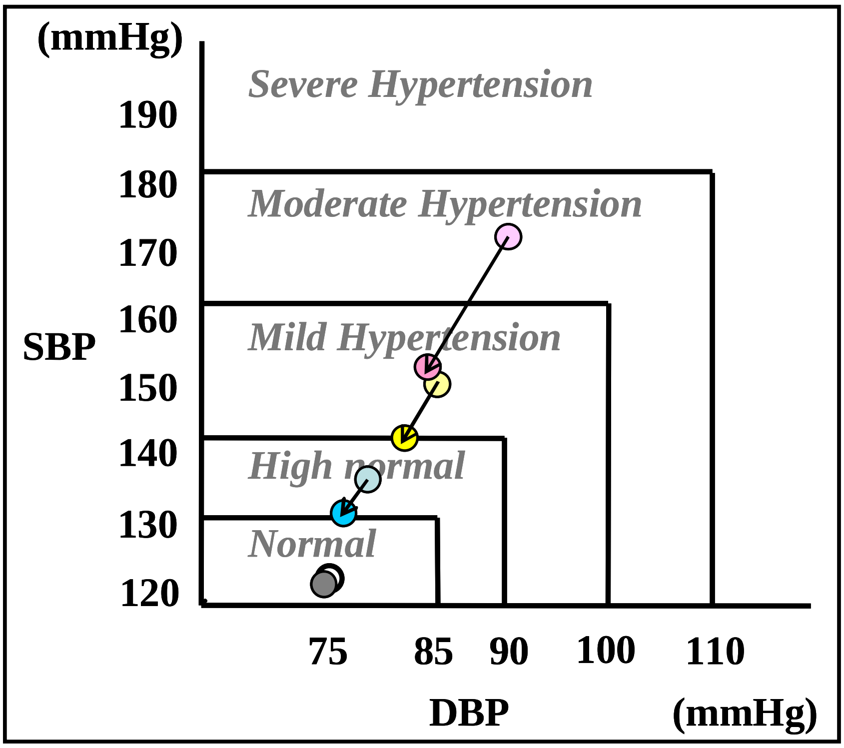


Figure 5. Changes of classification of hypertension level in all subjects (WHO/ISH, 1999).

The 5M group showed a tendency to improve at SBP and DBP. Also, the 1Y group showed significant improvement at SBP. On the other hand, the 2&3Y and 4&5Y groups showed increase SBP and DBP compared the values at water exercise program period (Table 1).

Table 1. BP values at water exercise program and follow-up periods (mean±SE).

Groups	n	Mean age (yrs)	SBP (mmHg)		DBP (mmHg)		Ratio of after finished program (%)	
			Immediately after	Lapsed time of after	Immediately after	Lapsed time of after	SBP	DBP
5M	13	56.1±5.7	134.4±4.6	127.5±3.2	77.7±2.4	76.8±3.2	94.9	98.8
1Y	12	61.5±7.5	138.0±4.9	130.7±3.5	78.8±3.3	76.9±3.7	94.7	97.6
2&3Y	12	63.2±12.5	129.7±4.9	132.0±2.8	76.8±3.1	81.3±4.3	101.8	105.9
4&5Y	13	62.1±13.0	127.5±4.5	131.2±7.0	72.0±2.8	77.7±3.9	102.9	107.9

DISCUSSION

Significant improvements of SBP or DBP were shown among the subjects in elder group. The reasons for improvements at BP were thought that the function of the parasympathetic nerve was raised. Furthermore, by the effects of the water exercise and water temperature, contraction and extension of function of the blood vessel might be improved.

In the follow-up the improvements of blood pressure were shown at the subjects who finishing water exercise program period and had passed within a year (5M and 1Y groups). In 5M and 1Y groups, 72.0 % (n= 18) of the subjects were tended to continue habitual exercise since finishing water exercise program period.

CONCLUSION

From these results, it was suggested that the short term water exercise program for 8 weeks will be able to decease blood pressure and also to motivate the habitual exercise to maintain and improve their blood pressure.

REFERENCE

1. Blair, S. N., Kohi, H. W., Barlow, C. E., Paffenberger, R. S., Gibbons, L. W. and Macera, C. A. (1995): Change in physical fitness and all-cause mortality: A prospective study pf healthy and unhealthy men. J. A. M. A., 273.

2. Roman, O. (1981): Physical training program in arterial hypertension. A long-term prosective follow up. Cardiology, 67, 230-243.

3. Sholander, P. F. (1962): Circulation adjustment in pearl divers. J. Appl. Physiol., 17, 184-190.

4. Tipton, C. M. (1991): Exercise, trainning abd hypertension: an update. Exercise and Sports Science Reviews, American College of Sports Medicine Seriese, 19, 477-505.

5. Urata, H., Tanabe, Y., Kiyonaga, A., Ikeda, M., Tanaka, H., Shindo, M. and Arakawa, K. (1987): Antihypertensive and volume depleting effects of mind exercise on essencial hypertention. Hypertension, 9, 245-252.

Effects of short term water exercise on the blood profile of elderly subjects from cold snowy region

Atsuko Hanai [1], Noriteru Morita[1], Koichi Okita[1], Takeo Nomura[2]

[1] Hokusho University, Ebetsu, Hokkaido, Japan
[2] University of Tsukuba, Tsukuba, Ibaraki, Japan

We examined effects of water exercise (WE) on the blood profile of elderly subjects from cold snowy region (CSR). Eleven subjects participated in a WE class for 6 weeks, twice a week for 90 min session (WE group). Eight sedentary subjects served as controls (C group). After WE period, SBP was significantly lowered in WE group compared with pre value ($p<0.05$). The lowered SBP indicates that WE has a beneficial effect on cardiovascular function. The overall blood profile seemed not to show any remarkable changes after WE. However, minor, but some changes were observed in measurements after WE. Taking all these results accounts as a whole, it is probable that a short-term WE program seems not have remarkable effects on blood profiles. However, some improvements observed after WE, implies a possibility that the WE is a beneficial exercise program for elderly people resides in CSR.

Key words: *water exercise, blood profile, elderly, cold snowy region*

INTRODUCTION

Inactivity during winter season because of the heavy snow is one of the serious problems for citizens in cold snowy region (CSR). To keep healthy lifestyle and maintain a certain level of fitness are essential factors for productive aging in CSR[1)]. Therefore, to encourage increased participation in exercise among elderly people is important task in CSR.

Water exercise (WE) is a beneficial exercise for citizens living in CSR, because allows to exercise during the winter season in indoor swimming pools. We have been reported the physical benefits of WE of elderly subjects from CSR[2)]. In this study, we examined effects of WE on the blood profile of elderly subjects from CSR. The purpose of the present study was to investigate the effects of the short term WE on blood profile of elderly in CSR.

METHODS

Eleven subjects participated in a WE class for 6 weeks, twice a week for 90 min session (WE group; mean age: 59.4yrs, SD: 9.2). Eight sedentary subjects served as controls (C group; mean age: 62.1yrs, SD: 8.5). Blood pressure (BP) were measured 3 times and averaged. Fasting venous blood samples were collected in the morning before and after the WE period. Fasting level of blood glucose, lipids, electrolytes, enzymes, metabolites, hematological measurements, and high-sensitivity CRP were also assessed.

Statistical analysis were carried out using Wilcoxon signed-ranks test. All statistical significance were set at $p<0.05$.

Table 1. Characteristics of the subjects

Group	Height (cm)	Body weight (kg	BMI (kg/m2)
Water exercise-group (n=11)	152.3 ± 7.2	57.3 ± 7.6	24.7 ± 3.2
Control group (n=8)	157.0 ± 5.0	61.2 ± 8.8	24.9 ± 4.1

(Mean±SD)

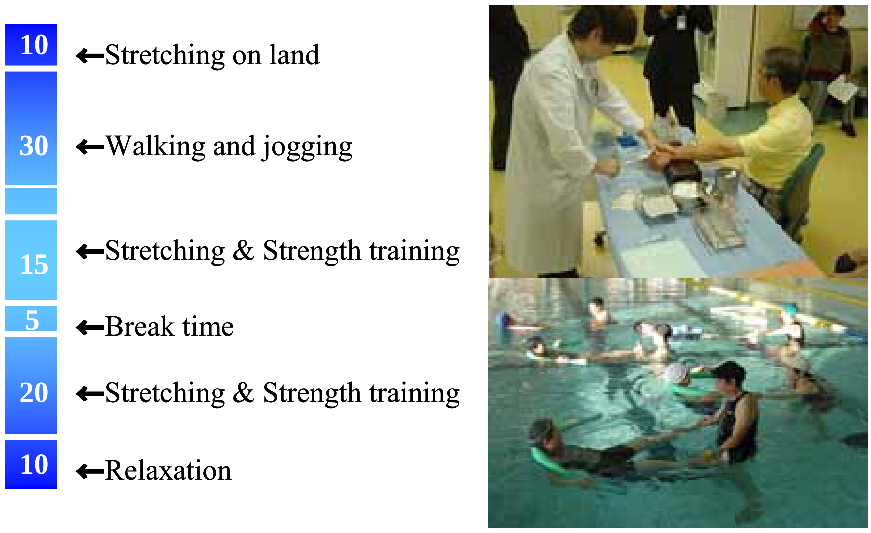


Figure 1. Contents of water exercise program (Photo above: Collecting blood samples, below: stretching and strengthening lower limbs using aqua noodles).

RESULTS AND DISCUSSION

Previously, we reported physical improvements after WE in the same subjects[1]. After WE period, SBP was significantly lowered in WE group compared with pre value ($p<0.05$). The lowered SBP indicates that WE has a beneficial effect on cardiovascular function. Though, not significant, LDL-cholesterol tended to decrease in WE group. This result might influence on lowered SBP. However, overall blood profile seemed not to show any remarkable changes after WE.

C-reactive protein (CRP), an obesity-related inflammatory maker, is a promising predictor for cardiovascular disease, showed no change in both groups. Previous paper

Table 2. Participants' blood profiles before and after water exercise period

Variable	Unit	Gourp	Pre mean	Pre SD	Post Mean	Post SD	***p***
Systolic blood pressure	mmHg	W	143.7	24.8	129.9	19.4	*
		C	131.6	22.6	136.4	19.7	
Diastolic blood pressure	mmHg	W	80.3	11.9	74.4	10.7	
		C	82.3	8.7	79.5	7.8	
Heart Rate	bpm	W	82.1	12.2	80.0	8.8	
		C	72.3	7.2	74.8	10.2	
AST(GOT)	IU/L	W	25.3	8.8	24.9	8.8	
		C	26.3	14.8	23.7	5.1	
ALT(GPT)	IU/L	W	24.0	13.5	24.3	10.9	
		C	24.2	16.9	21.4	8.4	
γ-GTP	IU/L	W	36.6	34.2	38.4	37.9	
		C	29.7	25.1	31.3	21.5	
Total Protein	g/dL	W	7.6	0.4	7.2	0.3	*
		C	7.2	0.2	7.1	0.2	
Albumin	g/dL	W	4.6	0.2	4.4	0.2	*
		C	4.4	0.2	4.3	0.2	*
Albumin/Globulin(A/G)	-	W	1.5	0.1	1.5	0.1	
		C	1.5	0.1	1.5	0.1	
Total cholesterol	mg/dL	W	225.1	28.0	220.4	32.7	
		C	220.8	36.6	231.1	35.1	
Triglycerides	mg/dL	W	93.1	31.4	119.3	62.7	
		C	98.3	72.1	92.4	49.9	
LDL cholesterol	mg/dL	W	138.9	28.6	128.9	30.6	0.07
		C	137.4	34.2	140.4	30.7	
HDL cholesterol	mg/dL	W	81.6	8.9	74.0	11.1	
		C	75.4	18.2	72.6	21.8	
Fasting Glucose	mg/dL	W	102.3	19.5	102.4	26.1	
		C	92.4	7.2	93.2	6.2	
Hemoglobin A1c	%	W	5.3	0.6	5.5	0.7	*
		C	5.1	0.3	5.1	0.4	
Fasting insulin	μU/mL	W	6.0	1.8	8.1	6.8	
		C	6.8	7.9	5.9	2.6	
Hematocrit(HCT)	%	W	43.5	3.1	43.6	3.9	
		C	41.6	1.5	42.3	2.4	
Hemoglobin(HGB)	g/dL	W	14.2	1.2	14.2	1.5	
		C	13.6	0.4	13.7	0.7	
mean corpuscular hemoglobin (MCH)	pg	W	29.3	1.0	30.3	0.8	*
		C	29.4	0.7	30.4	0.9	**
mean corpuscular hemoglobin concentration (MCHC)	%	W	32.7	0.4	32.5	0.6	
		C	32.1	1.4	32.4	0.6	
Mean Corpuscular Volume(MCV)	fL	W	89.7	2.8	93.4	3.0	
		C	90.3	2.5	93.9	2.3	**
Red blood cell (RBC)	10^6/μL	W	4.8	0.3	4.7	0.4	*
		C	4.6	0.2	4.5	0.3	*
White blood cell (WBC)	10^3/μL	W	6.0	1.4	5.5	1.4	*
		C	5.6	1.1	5.6	1.1	
platelet	10^4/μL	W	24.0	3.3	23.5	4.6	
		C	22.9	3.5	25.5	4.4	*
C-reactive protein	mg/dL	W	0.0	0.1	0.1	0.1	
		C	0.3	0.5	0.1	0.1	
Uric acid	mg/dL	W	5.1	1.2	4.8	1.0	
		C	4.4	1.4	4.4	1.3	
Creatinine	mg/dL	W	0.7	0.2	0.6	0.1	
		C	0.6	0.1	0.7	0.1	
blood urea nitrogen	mg/dL	W	14.0	2.6	14.4	1.8	
		C	14.6	4.3	15.4	3.9	
Na	mEq/L	W	140.7	1.4	140.3	1.7	
		C	140.9	0.9	140.6	1.5	
Mg	mg/dL	W	2.0	0.1	2.2	0.1	*
		C	2.1	0.1	2.2	0.1	*
K	mEq/L	W	4.0	0.5	3.8	0.4	*
		C	4.1	0.3	4.1	0.1	
Ca	mg/dL	W	9.3	0.3	8.9	0.3	*
		C	9.1	0.2	8.8	0.3	*
CL	mEq/L	W	100.9	2.1	101.7	2.8	
		C	102.9	1.2	103.9	2.1	

Variables are presented as mean ± SD. LDL denotes low-density lipoprotein; HDL, high-density lipoprotein; AST, aspartate aminotransferase; ALT, alanine aminotransferase; γ-GTP, γ-glutamyl transpeptidase.W, water exercise group; C, control group. *P<0.05, **p<0.01, before vs after water exercise period.

reported that 2 month exercise training with weight reduction disproportionately lowered CRP levels[3]. Though, 6 week water exercise program did not influence the subjects' body weight[2] in the present study.

Minor, but some changes were observed in measurements after WE (ex. Total protein, Albumin, Hemoglobin A1c, mean corpuscular hemoglobin (MCH), red blood cell (RBC), white blood cell (WBC), electrolyte (Mg, K, Ca); $p<0.05$, LDL-cholesterol; $p<0.07$), and also at controlled group(Albumin, MCH, mean corpuscular volume; MCV, RBC, platelet, Mg, Ca). Though, these changes were within normal range of values. Taking all these results accounts as a whole, it is probable that a short-term WE program seems not have remarkable effects on blood profiles. However, some improvements observed after WE, implies a possibility that the WE is a beneficial exercise program for elderly people resides in CSR.

CONCLUSION

The present study was to investigate the effects of short term water exercise on the blood profile of elderly subjects from cold snowy region. As a result, it implies that short term water exercise is a beneficial exercise program for elderly people resides in CSR.

REFERENCES

1) Suda T, Asao H, Morita I, Koji M(2005) Physical resources and the productivity of the elderly living in snowy regions. Bulletin of Northern Regions Research Center for Human Service Studies 11:61-77.
2) Hanai A, Yamamoto K, Hatakeyama T, Hareyama S, Morita N, Okita K, Nomura T(2006). Short-term water exercise effects of the physical fitness of elderly subjects from cold snowy region. Biomechanics and Medicine in Swimming X, 361-365.
3) Okita K, Nishijima H, Murakami T, Nagai T, Morita N, Yonezawa K, Iizuka K, Kawaguchi H, Kitabatake A(2004) Can exercise training with weight loss lower serum C-reactive protein levels? Arterioscler Thromb Vasc Biol. 24(10):1868-73.

ACKNOWLEDGEMENTS

The present study was supported by "Academic Frontier" project for Private Universities: matching fund subsidy from the Ministry of Education, Culture, Sports Science and Technology, 2004-2008.

Thermal sensation prediction model during elementary school swimming class

-Multiple effects of environment, physical characteristics and swimwear condition-

Hitoshi Wakabayashi[1], Seiji Arai[2], Yasuo Sengoku[3], Koichi Kaneda[4], Daisuke Sato[4], Yutaka Tochihara[1], Takeo Nomura[4]

[1] Faculty of Design, Kyushu University, Japan

[2] Kukizaki Junior High School, Japan

[3] Research Institute of Sports Science, Heisei International University, Japan

[4] Doctoral Program in Comprehensive Human Science, University of Tsukuba, Japan

This study investigated multiple effects of the environmental condition, physical characteristics, and swimwear condition on children's thermal sensation (*TS*) during elementary school swimming class. Sixth-grade elementary school children (n=68) participated in a swimming class for 8 times. They wore normal swimsuit or thermal swimsuit. Multiple regression analysis was performed to make estimation equation of *TS*. The following two regression equations were developed. The equations contain 3 predictors of water temperature (T_w), swimwear condition (*Suit*), and physical characteristics (surface area per body weight: *SA*/*BW* or *BMI*). ($TS = 0.58\ T_w + 1.21\ Suit - 126.2\ SA/BW - 11.3$, $TS = 0.58\ T_w + 1.21\ Suit + 0.139\ BMI - 17.8$). The result of standardized regression coefficients indicated that, T_w was the greatest contributor to *TS*, followed by *Suit*, and physical characteristics. The thermally comfortable area was indicated by the estimation equations.

Key words: *multiple regression analysis, environmental condition, physical characteristic, swimwear condition, elementary school swimming class*

INTRODUCTION

During cold water immersion, body heat is rapidly conducted away from human skin to the water. Children are especially likely to be affected by the cold water environment, because they have larger surface area per mass (Sloan and Keatinge, 1973). We reported that children with lower body fat had smaller tissue insulation and decreased rectal temperature more than the children with high body fat during leg pedaling exercise at cool water; and additionally, wearing a partial coverage wetsuit (PCWS) attenuated the decrease of rectal temperature compared to the normal swimwear condition (Wakabayashi et al., 2007a). In addition, we observed that even on cold weather day children wearing PCWS reported warm thermal sensation and kept the motivation in the class (Wakabayashi et al., 2007b). Since the environmental condition, physical characteristics, and swimwear condition may have complex effects on thermoregulatory response, it is necessary to investigate the multiple effects of these factors on children's response during immersion in water. This study investigated multiple effects of the environmental condition, physical characteristics, and swimwear condition on children's thermal sensation during elementary school swimming class.

METHODS

Sixth-grade elementary school children (n=68) participated in a swimming class for 8 times. Each class consisted of around 50 min swimming exercise program. Children's skin-fold thickness was measured at triceps and subscapular site, and mean skin-fold thickness (MSFT) was calculated. Body surface area (*SA*) was estimated based on their height (*H*) and body weight (*BW*) using the Fujimoto equation ($SA = 0.008883 \cdot BW^{0.444} \cdot H^{0.663}$) (Fujimoto et al., 1968), and *SA*/*BW* was calculated. Children wore normal swimsuit (NSS) or partial coverage wetsuit (PCWS). The PCWS used in this study was made of nylon-faced neoprene (2.0 mm thick), covering the thighs, trunk, upper arms, and neck. Water temperature (T_w), ambient temperature (T_a), relative humidity (%RH) and wet bulb globe temperature (WBGT) was measured during a swimming class. Children's thermal sensation (*TS*) and subjective exercise intensity (RPE; Borg, 1973) were asked after each class. The scale of *TS* consisted of 7 levels indicated by the following numbers: -3 = cold, -2 = cool, -1 = slightly cool, 0 = neutral, +1 = slightly warm, +2 = warm, and +3 = hot. Mean RPE value of each class were from 10.1 to 11.8 denoting "fairly light" activity. Multiple regression analysis was performed to make estimation equation of thermal sensation from environmental condition (T_w, T_a, WBGT), children's physical characteristics (*SA/BW*, *BMI*, MSFT) and swimwear condition (NSS, PCWS). A dummy variable was used in swimwear condition (NSS = 0, and PCWS = 1). All statistical significance were set at p<0.05.

RESULTS

Ranges of the variables in children's physical characteristics and the environmental condition during 8 times of swimming class are presented in Table 1 and 2, respectively.

Table 1 Children's physical characteristics

	Age (year)	Height (cm)	Weight (kg)	*BMI* (kg/m^2)	MSFT (mm)	*SA* (m^2)	*SA/BW* (m^2/kg)
min	11.2	127.5	24.6	13.4	4.5	0.92	0.027
max	12.2	160.5	58.6	22.7	19.8	1.57	0.038
mean	11.7	145.3	36.2	17.1	8.5	1.19	0.033
SD	0.3	6.1	5.8	1.9	3.2	0.11	0.002

Table 2 Environmental condition

	T_w (°C)	T_a (°C)	WBGT (°C)	%RH (%)
min	23.5	22.0	20.3	56.5
max	28.0	31.6	28.8	78.1
mean	25.5	26.8	24.5	64.8
SD	1.6	3.5	3.0	7.6

Based on the multiple regression analysis, the following two regression equations were developed. Both equations contain 3 predictors of environmental condition (T_w), swimwear condition (*Suit*), and physical characteristic (*SA/BW* or *BMI*). The regression coefficients of T_w and *Suit* were similar in both equations.

$$TS = 0.58\ T_w + 1.21\ Suit - 126.2\ SA/BW - 11.3 \qquad (1)$$

$$TS = 0.58\ T_w + 1.21\ Suit + 0.139\ BMI - 17.8 \qquad (2)$$

Standardized regression coefficients of two regression equations are presented in Table3.

The standardized regression coefficients of T_w and *Suit* were similar in both equations; and the absolute values of standardized regression coefficients were similar in *SA*/*BW* (equation 1) and *BMI* (equation 2). The adjusted square multiple *R* (R_{adj}^2), which represents the predictive ability, was similar in both equations.

Table 3 Standardized regression coefficients of each independent variable and the adjusted R^2

Equation No.	T_w	*Suit*	*SA/BW*	*BMI*	R_{adj}^2
equation (1)	0.523	0.341	-0.161	-	0.354
equation (2)	0.521	0.342	-	0.152	0.351

Figure 1 shows the relationships between *SA*/*BW* and T_w calculated from equation (1) when *TS* = -0.5, 0, and +0.5, with each swimwear (*Suit* = 0 or 1). The following equations (1-1, 1-2) were obtained when *TS* = 0, in each swimwear condition.

$T_w = 217.3\ SA/BW + 19.5$ (*Suit* = 0, *TS* = 0) (1-1)

$T_w = 217.3\ SA/BW + 17.4$ (*Suit* = 1, *TS* = 0) (1-2)

Figure 2 shows the relationships between *BMI* and T_w calculated from equation (2) when *TS* = -0.5, 0, and +0.5, with each swimwear (*Suit* = 0 or 1). The following equations (2-1, 2-2) were obtained when *TS* = 0, in each swimwear condition.

$T_w = -0.24\ BMI + 30.8$ (*Suit* = 0, *TS* = 0) (2-1)

$T_w = -0.24\ BMI + 28.7$ (*Suit* = 1, *TS* = 0) (2-2)

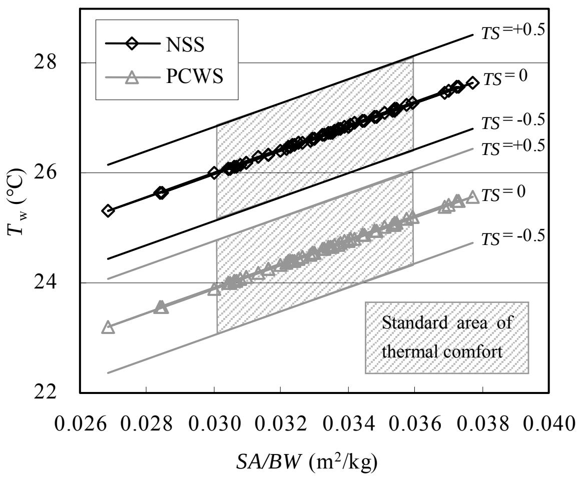


Figure 1 The relationship between *SA*/*BW* and T_w at *TS* = -0.5, 0, +0.5

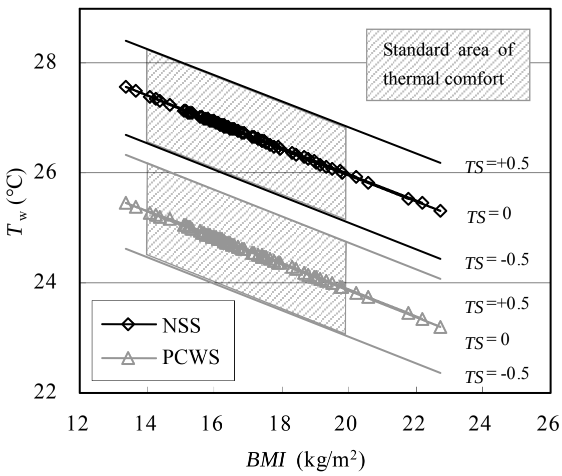


Figure 2 The relationship between *BMI* and T_w at *TS* = -0.5, 0, +0.5

DISCUSSION

Based on the multiple regression analysis, regression equation (1) and (2) were developed. Both equations contain 3 predictors of environmental condition (T_w), swimwear condition (*Suit*), and physical characteristic (*SA*/*BW* or *BMI*). The result of standardized regression coefficients (Table 3) indicated that, T_w was the greatest contributor to *TS*, followed by almost great contributor swimwear condition, and physical characteristics (*SA*/*BW* or *BMI*) had smaller effect on *TS* compared to the previous two predictors.

In this study, each regression equation contains predictor of physical characteristic (*SA*/*BW* or *BMI*). Sloan and Keatinge (1973) have suggested a relationship between decrease of core body temperature and children's *SA*/*BW* during submaximal swimming in cool water. The equation (1), which contains *SA*/*BW* as a predictor of physical characteristic, represents that children with greater *SA*/*BW* feel colder thermal sensation. Also, the equation (2), which contains *BMI* as a predictor of physical characteristic, represents that children with greater *BMI* feel warmer thermal sensation. Since the regression coefficients of each predictor was similar in both equations, and the R_{adj}^2, which represents the predictive ability, was similar in both equations, we can use *BMI* as the predictor of physical characteristic to estimate their *TS* equally with *SA*/*BW*.

In both equations (equation 1, 2), the regression coefficients of *Suit* were 1.21, which represents that wearing PCWS (*Suit* = 1) makes children feel warmer *TS* by 1.21 compared to NSS condition (*Suit* = 0). From the equation (1-1) and (1-2), the difference between constant terms of these two equations was 2.1, which represented that wearing PCWS could obtain a thermal effect similar to the 2.1°C increment in T_w compared to NSS condition. Similar result was observed between equation (2-1) and (2-2). The present study revealed the thermal effect wearing PCWS was worthy to 1.21 warmer *TS* and the increase of T_w by 2.1°C based on the results using the multiple regression analysis.

The international standard organization ISO7730 (2005) cites that, when *TS* (7 point scale) was at the range from -0.5 to +0.5, more than 90% of the population would be satisfied of the thermal environment. Therefore, in the present study, we showed the relationships between *SA*/*BW* and T_w calculated from the equation (1) when *TS* = -0.5 or +0.5, in each swimwear condition (Figure 1). The area between the regression lines when *TS* = -0.5 and +0.5 could be considered to indicate the thermally comfortable area. Additionally, we defined the shaded area observed in Figure 1 as standard area of thermal comfort during swimming class. This standard area includes 5th-95th percentile (90%) of children participating in this study according to the histogram of their *SA*/*BW*. Using the same process, we defined standard area of thermal comfort from the relationship between *BMI* and T_w (equation 2, Figure 2).

REFERENCE

1) ISO7730 (2005) Moderate thermal environments –Determination of the PMV and PPD indices and specification of the conditions for thermal comfort- Geneva, International Organization for Standardization.

2) Sloan REG, Keatinge WR (1973) Cooling rates of young people swimming in cold water. J Appl Physiol 35(3): 371-375.

3) Wakabayashi H et al. (2007a) Insulation and body temperature of prepubescent children wearing a thermal swimsuit during moderate intensity water exercise. J Physiol Anthropol 26(2): 179-183.

4) Wakabayashi H et al. (2007b) The effectiveness of wearing thermal swimsuits during elementary school swimming class: focusing mainly on students' cold sensation and formative evaluation on the class. Japan J Phys Educ Hlth Sport Sci 52(2): 201-211.

Poster presentation

Day 2 – 26th March

Stroke technique during constrained swimming

Michel Sidney, François Potdevin, Jeanne Dekerle, Patrick Pelayo, Morgan Alberty.
Human Movement Studies Laboratory, University of Lille 2, Rochin, France

The aim of this study is to assess the technical evolutions under constrained swimming i.e at constant velocity with a fixed stroke rate value. Ten trained swimmers performed a maximal 400-m front crawl test (V_{400}), and a set of time to exhaustion (TTE) at 95, 100, and 110% of V_{400} at an individual stroke rate value (corresponding to the average value of freely choosen stroke rate adopted in previous set of same TTE). Durations of TTE, relative durations of arm stroke phases and arm coordination were analysed. Durations of TTE were 333±54s, 177±58s, and 47±10s for TTE at 95, 100, and 110% of V_{400} respectively. For each TTE, all variables were steady, suggesting a stabilisation of the stroke technique. According to previous resutls, stroke rate can be seen as a useful tool for controlling the arm technique during paced exercise.

Key words : *task constraint, arm coordination, front crawl*

INTRODUCTION

The way to high performance level needs technical developement that is notably transduced by an enhancement of the distance travelled per stroke cycle (1, 3, 6). Coupled to an appropriate rate of application of these stroke cycle this give a swimming speed specific to the characteristics of the race. Another characteristic of the expert swimmer is the maintenace of the stroking parameters so that the swimming speed remain more or less unaffected during the whole race (4). A mean to develop this latter ability is to design training set where speed and the number of stroke cycle per unit distance are imposed. Such a double task constraint is assumed to be sufficient to stabilize stroke technique. This assumption have not been verified yet. Based on the dynamical theories of motor organisation, the study of Seifert et al. (9) showed that the best determinants of arms coordination in front crawl stroke are first stroke rate and second velocity. If so, when a swimmer is asked to adopt a given velocity alongside a given stroke rate, a stabilisation of the temporal organisation of his stroke cycle could emerge, fitting the above mentionned assumption.

The aim of this study is to assess the technical evolutions under constrained swimming i.e at constant velocity with a fixed stroke rate value. It is hypothesized that the control stroke rate druing paced exercise induce a stabilization of the temporal structure of the stroke cycle.

METHODS

Ten well trained swimmers (20.3 ± 1.7 years; eight males and two females) volunteered for this study. Mean values (± SD) of height, body mass and arm span were, 1.8 ± 0.06 m and 1.7 ± 0.07 m, and 73 ± 5 kg and 62 ± 5 kg, and 1.87 ± 0.05 m and 1.72 ± 0.07 m respectively for males and females.

Their performances in the 400 m front crawl stroke were 280.23 ± 13.73 s and 322.73 ± 12.47 s, which correspond to a mean percent of 76.8 ± 3.7% and 73.3 ± 2.7% of the short course pool world record for men and women, respectively.

First, swimmers performed a 400 m at maximal intensity for the determination of V_{400}. Subjects were then required to do two sets of three swims for a Time To Exhaustion (TTE in s) at targeted velocities which corresponded to 95%, 100%, and 110% of V_{400} (TTE_{95}, TTE_{100}, and TTE_{110} respectively).

The swimmers were filmed in a sagittal plain by another operator during all the tests using two cameras; one above the surface (JVC Mini DV GR-DVX 407EG operating at 25Hz and contained in a box JVC WR-DV96) and one below the surface of the water (Sony Mini DV DCR-HC40E operating at 25 Hz and contained in a waterproof Sony HandyCam MPK-DVF6). Each view were post synchronized with a visual signal.

For the first set, (named “Free”), only velocities was imposed. For each TTE, times of stroke cycles (s) were measured cycle by cycle using a PC software developed in our laboratory. An individual average SR value was determined for each TTE so that these values were used for the second part of the testing procedure. For the present study, no further analysis have been conducted on these tests.

For the second set, (named “Control”), velocities and stroke rate were imposed. Swimmers were required to repeat the set of TTE previously described (TTE_{95}, TTE_{100}, and TTE_{110}) with an imposed SR which corresponded to their mean individual SR previously measured during TTE of the set “Free”. The mean SR was imposed with a metronom (Tempo Trainer, Finis ®) placed in the swimmer’s cap. Swimmers were obliged to maintain the stroke rate as long as possible.

For the analysis of the changes in the variables, TTE were splitted into 6 epochs corresponding to 0, 20, 40, 60, 80, and 100% of the TTE.

The swimming velocity (V in $m.s^{-1}$) was calculated by the PC software,. The stroke length (SL in m) was calculated as the ratio between V and SR. For each epoch, the mean values of SR, SL, and V of the corresponding lap were extracted. Videos analysis was made using DartTrainer software (Version 4.0.5 DartFish TeamPro) which allows the analysis of each stroke with an accuracy of 0.02 s. For each epoch, three consecutive arm stroke cycles were broken down into four distinct phases according to Chollet et al., (2); A : entry and catch, B: pull, C: push, and D: recovery. Their durations were then expressed in second (A, B, C, and D in s).

From this measurement, the beginning and the end of the propulsive actions of both arms can be detected. This allows the calculation of the Index of Coordination (IdC). The IdC characterizes coordination patterns from the measurement of the lag time (s) between the beginning and the end of the propulsive phases of each arm. IdC is expressed in percentage of the mean duration of the stroke. The complete methodology is described in the Chollet et al., (2) study.

Statistical analysis

Means and standard deviations (SD) were used to represent the average and the typical spread of values of the studied variables. A one-way ANOVA for repeated measures was used to compare the mean values at each epoch of analysis (0, 20, 40, 60, 80, and 100% of each TTE) for each TTE for the set Control. The level of significance was set at the 0.05 level of confidence. This statistical analysis was realized with the use of the STATISTICA 6.0 software for PC.

RESULTS

The mean durations of TTE of the first set were 670 ± 117s, 238 ± 43s, and 68 ± 14s for TTE_{95}, TTE_{100}, and TTE_{110}, respectively. For the second set the mean duration were 333 ± 54s, 177 ± 58s, and 47 ± 10s for TTE_{95}, TTE_{100}, and TTE_{110}, respectively. The mean reduction of durations for each TTE between both sets were 48.89 ± 11%, 25.65 ± 16.24%, and 30.53 ± 7.9% for TTE_{95}, TTE_{100}, and TTE_{110}, respectively. The decrease in TTE duration between both sets is significant only for TTE_{95} and TTE_{100} ($p<0.05$).

The mean imposed velocity values were 1.28 ± 0.1m.s^{-1}, 1.38 ± 0.1m.s^{-1}, and 1.51 ± 0.11m.s^{-1} for TTE_{95}, TTE_{100}, and TTE_{110} respectively. The absolute durations of the stroke phases are reported in Table 1. Statistical procedure failed to detect any significant changes in the temporal properties of the stroke cycle during TTE of the set 'Control'.

Table 1 : Mean values (±SD) of the absolute durations of the glide+catch (A), pull (B), push (C) and recovery (D) phases and of Index of Coordination (IdC) at the beginning (0%) and the end (100%) of each TTE.

		A (s)	D (s)	B (s)	C (s)	IdC (%)
		A+D (s)		**B+C (s)**		
TTE_{95}	0%	0.66 ± 0.16	0.37 ± 0.04	0.47 ± 0.05	0.40 ± 0.03	-3.82 ± 2.89
		1.03 ± 0.16		**0.87 ± 0.07**		
	100%	0.62 ± 0.16	0.36 ± 0.04	0.47 ± 0.03	0.40 ± 0.04	-3.60 ± 3.45
		0.99 ± 0.13		**0.87 ± 0.06**		
TTE_{100}	0%	0.59 ± 0.13	0.36 ± 0.04	0.42 ± 0.04	0.39 ± 0.05	-3.72 ± 3.85
		0.95 ± 0.12		**0.82 ± 0.07**		
	100%	0.59 ± 0.12	0.35 ± 0.03	0.43 ± 0.02	0.40 ± 0.06	-2.95 ± 3.32
		0.94 ± 0.11		**0.83 ± 0.08**		
TTE_{110}	0%	0.50 ± 0.14	0.34 ± 0.03	0.39 ± 0.02	0.34 ± 0.03	-2.84 ± 4.50
		0.84 ± 0.14		**0.74 ± 0.02**		
	100%	0.50 ± 0.12	0.33 ± 0.02	0.41± 0.02	0.34 ± 0.02	-2.54 ± 4.55
		0.83 ± 0.12		**0.75 ± 0.04**		

DISCUSSION

The aim of the present study was to analyse the changes in the temporal organisation of the arm stroke cycle and the arm coordination during paced front crawl tests swum with constant stroke rate value.

Our results showed a stability of the absolute durations of the stroke phases during TTE. Our hypothesis is verified and confirmed the assumption made by coaches i.e. the stroke technique, at least for the temporal properties of arm stroke cycle, is stabilized when the stroke rate is controlled during paced exercise. A stability of the arm coordination is thus observed. A recent study that applyed dynamical theories of motor organisation applied in swimming demonstrated that stroke rate could act as a task constraint, which would induce the emergence of a particular arm coordination as well as a particular temporal organisation of the arm stroke cycle (9). Our results are in line with those assumptions and strengthen the role of stroke rate, coupled with speed, in the determination of a particular motor organisation of the swimmers (7-9). This double task constraint could represent a strong scaling factor for the stabilisation of the swimming technique. If coaches are looking for stabilizing the technique of their swimmers, and more precisely the coordination the propulsive action of the arms in the swims, the use of these two constraints seems approriate. In accordnace with previous studies (7-9), our results suggest the stroke rate as the first determinant of motor organisation in swimming.

This double task constraint (pace + stroke rate control) led to a reduction in the duration of the exhaustive exercise, for each velocity tested. Such an impact can be explained by the intensities the tests were swum at. Indeed, Dekerle et al. (5) showed that during exercise performed above maximal lactate steady state speed, i.e. at velocities above 88% of V_{400}, swimmers need to continuously adapt their SR-SL combination to keep the imposed pace. In the present study, these compensatory mechanisms at high intensities are not possible as the same SR-SL combination had to be kept. This would induce a premature ending of the exercise. Such a reduction in TTE also suggest a workload that differ from paced exercices at freely choosen SR. Considration of physiological parameters during those exercises, conducted till exhaustion, could allows an estimation of the alteration of the workload imposed to the swimmer.

Our results showed that throught time as long as the pace and SR are kept, temporal properties of the arm stroke cycle remain stable. It means that even if a swimmer is exhausted, the control of the pace and the stroke rate induces a given mode of coordination. For example, during a taper, after having determining the appropriate modification of the SR-SL combination corresponding to the highest race pace the swimmer might swim at, he could be asked to keep this pace and SR in order to train at the given mode of coordination for a certain time, this possibly simulating the end of a race.

Finally, our results suggest that to learn and stabilize a particular arm coordination, interval training set where both speed and stroke rate are imposed, could be designed (as TTE duration decreased significantly from set 'Free' to set 'Control'). The rest given to the swimmer between repetitions could allow him to lengthen the time swam at a particular arm coordination. The duration of repetitions could be designed with upper limits that corresponds to the values observed in the different speed investigated in the present study. However, further investigation are needed to find the ratio between exercise/rest that allows the greater lentgthenning of time exercise.

BIBLIOGRAPHY

1. Chollet D, Pelayo P, Delaplace C, Tourny C, Sidney M. (1997). Stroking characteristic variations in the 100-m freestyle for male swimmers of differing skill. Percept Mot Skills, 85(1): 167-177.
2. Chollet D, Chalies S, Chatard JC. (2000). A new index of coordination for the crawl : description and usefullness. Int J Sports Med, 21(1): 54-59.
3. Costill DL, Kovaleski J, Porter D, Kirwan J, Fielding R, King DL. (1985). Energy expenditure during front crawl swimming: Predicting success in middle-distance events. Int. J. Sports Med, 6: 266-270.
4. Craig AB, Pendergast DR. (1979). Relationships of stroke rate, distance per stroke and velocity in competitive swimming. Med Sci Sports Exer, 11(3): 278-283.
5. Dekerle J, Nesi X, Lefevre T, Depretz S, Sidney M, Huot-Marchand F, Pelayo P. (2005). Stroking parameters in front crawl swimming and maximal lactate steady state speed. Int J Sports Med, 26: 53-58.
6. Pelayo P, Alberty M, Sidney M, Potdevin F, Dekerle J. (2007). Aerobic potential, stroke parameters, and coordination in swimming front-crawl performance. Int J Sports Physiol Perf, 2: 345-357.
7. Potdevin F, Bril B, Sidney M, Pelayo P. (2006). Stroke frequency and arm coordination in front crawl swimming. Int J Sports Med, 27: 193-198.
8. Potdevin F, Pelayo P, Delignières D, Dekerle J, Alberty M, Sidney M. (2003). Does stroke rate determine swimming velocity values and coordination ? In : Chatard JC (ed.) Swimming Science IX, University of Saint Etienne (press), 163-168.
9. Seifert L, Chollet D, Rouard A.(2007). Swimming constraint and arm coordination. Hum Mov Sci, 26: 68-86.

Men’s Freestyle Angle of Catch Point, Finish Point and Kick Point

Noriko Inada, Kohei Kawamoto, Takahisa Ide
Brophy College Preparatory, Facility of Sports Campus, Phoenix, Arizona, USA

This study focused on explaining the reasons for the increased timing in men’s 100 meter freestyle. Three representative freestyle sprint swimmers’ angle of catch point, finish point, and kick point for last forty years were analyzed. Mark Spitz from 1970’s, Matt Biondi from 1980’s and Anthony Arvin from 2000’s were picked up for the present investigation. 1970’s, Mark Spitz used S-pattern stroke technique. 1980’s, Matt Biondi used technique of rolling the body from side to side. 2000’s, Anthony Ervin used technique of rolling only the upper body from side to side. It was concluded that future sprint freestyle champions may employ the straight arm while only rolling the upper body with a steep catch, finish and kick point angle to further enhance sprint freestyle performance.

Key words: *swim technique*

INTRODUCTION

The technique of catch point and kick point for sprint freestylers have developed as times for the sprint freestyler champions in the Olympics have drastically improved. As for the sprint freestyle, in the last 40 years, it has become clear that the improvement of time is highly correlated to the angle of the catch point, finish point (Yoshimura & Takahashi, 1997) and kick point in a stroke (Maglischo, 2003). The catch point is integral to the freestyle stroke because when the catch is done correctly, it allows the arm to move deep enough in the water so that the undersides of the upper arm, the forearm and the palm of the hand to be placed in a backward-facing position where they can apply propulsive force effectively (Maglischo, 2003). The finish point is the fastest portion of the stroke. The hand glides towards the back of the stroke, while the hand is making an upsweep (Yoshimura & Takahashi, 1997). The kick point is the phase when leg travels down and slightly back during the downbeat. Because of the rapid extension that takes place at the knee, this is the most propulsive phase of the entire freestyle stroke (Maglischo, 2003). The purpose of this article is to difference angle of each degrees of between the S-patterns stroke technique, the technique of rolling the body from side to side, and technique of rolling only the upper body from side to side. Also, this study was intended to provide helpful information for the swimmers to achieve the high goal of representing Japan during the 2008 Beijing Olympic Games.

METHODS

Mark Spitz from 1970's, Matt Biondi from 1980's and Anthony Arvin from 2000's were picked up for the present investigation. Spitz won seven gold medals at the 1972 Olympic Games in West Germany swimming a 51.22 seconds in the 100 meter freestyle. Matt Biondi won 11 medals in three Olympic Games from 84 Los Angels to 92 Barcelona. Biondi's 100 meter freestyle personal best time was 48.55 seconds. Ervin won the 50 freestyle at the 2000 Sydney Olympic Games and a personal best of 48.33 seconds in the 100 freestyle (USA Swimming, 2006).

Data used for this study was collected by using Dartfish (DartTrainer2.5-Standard), an underwater stroke analysis software, focusing on the angle of the catch point, finish point, and kick point. Photographs, videos, data from television, books, and the magazines which related to the stroke of freestyle were collected. Anthony Ervin's underwater video was filmed at the Oahu Club in Hawaii, USA in September 17, 2005 (see Figure 2). That video was Ervin's 200 meters freestyle relay time trial. Matt Biondi's underwater video from USA Swimming filmed underwater by at a laboratory pool (see Figure 1). Mark Spitz's pictures were from "Competitive Swimming Manual for Coaches and Swimmers" (Counsilman et al., 1982). We put these videos and pictures on the Dartfish, and then we analyzed each swimmer's catch point, finish point, and kick point.

The stroke pattern was investigated from the fallowing view points. The S-pattern stroke is the hand and arm movement in an S-pattern under the body (Maglischo, 2003), while the arm in the water moves forward. During the S-pattern stroke, the hands and arms move across to the body. The rolling of the body from side to side, while the stroke arm is in the water, the rolling of the hips from side to side prevents the stroke from going under the body (Maglischo, 2003). In fact, the hands and arms move far away from the body. The rolling of only the upper body from side to side technique, causes the arm in the water and shoulders to move from side to side, but the hips do not move from side to side (Ide, 2007).

RESULTS

Mark Spitz catch point, finish point, and kick point was 6 degrees. Mark Spitz used a S-pattern stroke technique. From these results, we mentioned by Spitz entered arm in the water, and then immediacy caught the water by the analysis from pictures. After the catch, his arm moves across his body making the traditional S- stroke. Spitz's hips were moving forward on every stroke, so his kick was notable to extend deeper in the water. Matt Biondi had a 25 degree catch point, 63 degree finish point (see Figure 1), and an 11 degree kick point. Matt Biondi used the technique of rolling the body from side to side. We could see Biondi's armed entered the water, but he pauses his stroke before he catches the water. This pause is possible because his hips and shoulders roll from one side to side. After the catch point, his hips move horizontal to the water. Then the arm moves to the finish point. So Biondi's finish point was smaller in magnitude than Ervin's finish point. Biondi's hips were rolling on every stroke, so his kick could not extend deeper. Anthony Ervin had a 104 degree catch point, 76.6 degree finish point, and a 12.5 degree kick point (see Figure 2 and Table 1). Anthony Ervin used the technique of only rolling the upper body from side to side. We could see when Ervin's arm entered the water, he waits to catch. Because his shoulders roll from side to side, but in contrast to Biondi, his hip does not roll. After the catch point, Ervin's arm progresses to the finish point. The shoulder rolling only movement of Ervin's stroke allowed his hip to remain stationary and therefore allowed his kick to extended much deeper the Spitz or Biondi.

Table 1 Result of the source for the angle of a catch point, the angle of the finish point, the angle of the kick, and 100 meter freestyle times with Anthony Ervin, Matt Biondi, and Mark Spitz

	angle of a catch point	angle of a finish point	angle of a kick point	Freestyle 100 mater
Anthony Ervin	104 degrees	76.6 degrees	12.5 degrees	48.33 seconds
Matt Biondi	25 degrees	63 degrees	11 degrees	48.55 seconds
Mark Spitz	6 degrees	6 degrees	6 degrees	51.22 seconds

Figure 1 The finish point of Matt Biondi

Figure 2 The finish and kick of Anthony Ervin

DISCUSSION

The angle of the catch point, finish point and kick point were analyzed for three representative freestyle sprint swimmers. Anthony Ervin and Matt Biondi demonstrated very similar angles of finish and kick point, except angle of catch point. So additional investigation were conducted. Eight dots for Ervin and Biondi's under water picture were plotted. Ervin's dots shown beautiful half of one circle while Biondi's dots shown half of two circles. This result indicate that Ervin's stroke carries the water all way through in his stroke. Biondi's stroke carries the water half way of his stroke, then he carries the water again. Biondi's stroke has gap between the first circle to second circle (see Figure 3). !

Over the years, as freestyle sprint times have improved, we have observed the angle of the catch point, the finish point and the kick point magnitude of angle were increasing each year. This is more than a casual relationship and if there is a strong relationship between the angle of the catch point, the finish point and kick point, coaches should encourage swimmers to emulate these techniques.

Figure 3   The eight dots of Anthony Ervin and Matt Biondi

CONCLUSION

Anthony Ervin used a catch point at a very step angle, and holds more water and holds the water until the finish more effectively than past Olympic champions. Three representative freestyle sprint swimmers were analyzed in this study and it was concluded that only Ervin stroked with a straight arm technique and the technique of rolling only the upper body from side to side. Based on the above observations, future sprint freestyle champions may employ the straight arm while only rolling the upper body with a steep catch, finish and kick point angle to further enhance sprint freestyle performance.

REFERENCES

1. Counsilman JE, Mitsumasa Miyashita, Takeo Nomura, and Harusuke Naito (1982). Competitive Swimming Manual for Coaches and Swimmers. Tokyo, Japan: Taishukan Shoten, 176-177.

2. Ide Takahisa (2007). The Effects of Swimming Men's Sprint Freestyle Coaching for Stroke Technique for 2008 Beijing Olympic Games, Tokyo, Japan: Nihon University, Graduate School of Social and Cultural Studies, 14-20.

3. Maglischo EW (2003). Swimming Fastest. Champaign: Human Kinetics, 80-82, 96, 116-117.

4. USA Swimming (2006). Pan Pacific 2006 Swimming Championship.

5. Yutaka Yoshimura, and Yusuke Takahashi. (1997). Swimming. Tokyo, Japan: Ikeda Shoten, 20.

Sweat loss and fluid intake during swimming training in winter and summer at an indoor swimming pool: A field study

Akihiro Taimura[1], Masaru Matsunami[2], Masashi Sugawara[3], Masahiro Taguchi[4] and Shoichiro Taba[4]

[1] Nagasaki University, Faculty of Environmental Studies, Japan

[2] Beppu Mizobe Gakuen College, Japan

[3] Nagasaki University, Faculty of Education, Japan

[4] Fukuoka University, Faculty of Sports Science, Japan

This study aimed to clarify weight loss and fluid intake during swimming training in winter and summer at an indoor swimming pool. The subjects were thirteen male college swimmers. The body weight before and after training, the volume and the frequency of fluid intake and urination during training were measured. Sweat loss and fluid intake during swimming training was related to pool condition. However, there was no difference in the fluid intake ratio and the frequency of fluid intake between summer and winter. Because there is considerable variability in sweat loss and fluid intake between individuals, individualized fluid replacement program are recommended during training. It is considered that swimmers should have more fluid intake before/during swimming training to prevent dehydration, especially in summer.

Key words: *Weight loss; Sweat loss; Fluid intake; Pool condition; Training*

INTRODUCTION

Many investigations on sweat loss and fluid intake during exercise have been reported. The results indicated that fluid intake before and during exercise is important to maintain performance and to prevent dehydration in a hot environment (1, 3). Few of these studies, however, focused on sweat loss and fluid intake during swimming exercise. Robinson and Somers(4), Taimura *et al.*(5) reported about weight loss during swimming exercise. Cox GR *et al.*(2) had estimated body mass changes and voluntary fluid intakes of elite level water polo players and swimmers. They reported that there was a wide individual variation in sweat loss and fluid intake of both water polo players and swimmers. The differences in their data concerning weight loss were thought to be due to the effect of water temperature and exercise type or intensity. However, there were few reports on sweat loss and fluid intake during swimming training in different pool conditions. This study aimed to clarify sweat loss and fluid intake during swimming training in winter and summer at an indoor swimming pool.

METHODS

Subjects: The subjects for this study were twelve male college swimmers (Winter: age, 21.0 ± 1.6 y; height, 176.1 ± 3.4 cm; body weight, 72.7 ± 3.9 kg; %body fat, 12.7 ± 1.4 %, Summer: age, 20.7 ± 1.5 y; height, 174.5 ± 5.4 cm; body weight, 71.3 ± 5.2 kg; %body fat, 12.6 ± 1.3 %). They trained regularly for 10 times per week, 2.5 hours each time. All subjects were given both verbal and written information concerning the nature, aims, possible risks, and benefits of this study and gave their written informed consent in accordance with the guidelines set forth by the Declaration of Helsinki. This study was approved by the local Ethnical Committee.

Measurements: The measurements for this study were performed on December 28th, 2005 and July 31st, 2006. On each day, environmental temperatures (RM: Room temperature, GT: Grobe Temperature %Rh: Relative humidity and water temperature) were measured every fifteen minutes during swimming training on the pool deck and the average was considered as the value (Table 1). The body weight before and after exercise in a swimsuit was measured with a digital scale (UC-300, A&D, Japan) with an accuracy of ±50g. During swimming training, a commercially available sports drink (Pocari Sweat, Otsuka, Japan) was provided in an individually identified drink bottle for each swimmer. The concentration and temperature of fluid was determined by the swimmer. Swimmers were allowed to take fluid *ad libitum*. The volume of fluid intake during training was measured each time a swimmer had taken fluid by weighing the bottle weight with a digital scale (KD404, TANITA, Japan) with an accuracy of ±1g. The body weight loss was determined from the body weight before and after exercise. The sweat loss during exercise was calculated from the weight loss, the fluid intake and urine volume.

The schematic representation of the measurement protocol is shown in Fig. 1.

Specific calculations:

1. Environmental temperature

・WBGT (Wet Bulb Globe Temperature Index) = 0.7 x NWB + 0.3 x GT

2. Weight loss, sweat loss and fluid intake ratio

・Weight loss (g) = Body weight before training - Body weight after training

・Sweat loss (g) = [(Body weight before training - Body weight after training) + Fluid intake volume during training – the volume of urination during training]

・Fluid intake ratio (%) = Fluid intake / Sweat loss x 100

Statistical analysis: All data are expressed as mean ± standard deviation. Correlation coefficients were calculated to explore the relationships between selected parameters. Statistical significance was established at the $P < 0.05$ level.

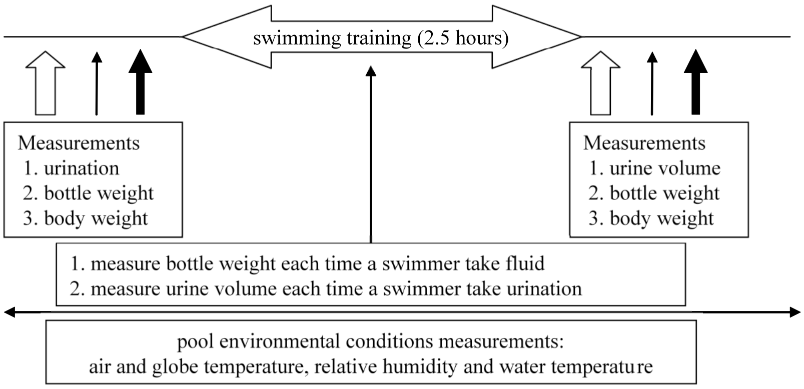


Figure 1. Schematic representation of the measurement protocol

RESULTS AND DISCUSSION

The environmental temperatures are presented in Table 1. The mean water temperature and WBGT during exercise were 27.6 ± 0.2 and 18.2 ± 2.1 in winter and 31.5 ± 0.1 and 28.9 ± 0.1 in summer, respectively. There was a significant difference between winter and summer. The regulation temperature of water in which swimming competitions are held is between 25°C and 28°C according to the Facilities Rules (FR 2.11) of the Federation Internationale de Natation (FINA). Body temperature is raised due to the increase of water temperature and exercise intensity (6). The environmental conditions in summer were significantly larger heat strain than those of in winter at the indoor pool and might cause large amounts of dehydration for swimmers.

Table 1. Pool environmental conditions during training

		room temperature (°C)	relative humidity (%)	globe temperature (°C)	WBGT (°C)	water temperature (°C)
Winter	Mean	18.1	77.3	23.2	18.2	27.6
	S.D.	1.4	1.3	4.1	2.1	0.2
Summer	Mean	31.2 *	75.1	31.6 *	28.9 *	31.5 *
	S.D.	0.7	4.9	0.8	0.1	0.1

WBGT: Wet Bulb Globe Temperature, $*P < 0.05$

The sweat loss, fluid intake volume, frequency of fluid intake, fluid intake ratio and the volume of urine during training are presented in Table 2. Sweat loss and fluid intake were 855.6 ± 417.8g, 523.3 ± 294.9g in winter and 1504.2 ± 537.5g, 924.8 ± 500.6g in summer, respectively. There was a significant difference between winter and summer. This difference is thought to be an effect of water temperature. The volume of urination in winter (251.0 ± 207.2g) was significantly larger than that in summer (78.9 ± 54.0g). The fluid intake ratio and fluid intake frequency were 47.9 ± 22.6% (range 5.9 – 77.1 %) and 9.1 ± 4.3 times in winter and 56.8 ± 21.3% (range 10.7 – 83.8%) and 11.8 ± 2.9 times in summer. There was no significant difference between winter and summer. Fluid intake ratio was lower than that of other sporting events (82.7% for American football, 76.4% for college soccer, 85.4% for junior soccer, 61.9% for college basketball, and 67.9% for kendo, which we had measured (7).

The weight loss ratio was significantly greater in summer (2.3 ± 0.9% (range 1.1 – 4.0%)) than in winter (1.5 ± 0.5% (range 0.7 – 2.5%)). There is large inter-individual variability in both the fluid intake ratio and the weight loss ratio. According to The American College of Sports Medicine exercise and fluid replacement Position Stand evidence statements, dehydration (> 2% body weight) can degrade aerobic exercise performance, especially in warm-hot weather (1). The weight loss ratio in this study was 2.3 ± 0.9% in summer and two swimmers had dehydrated in excess of 2.0% in winter. Swimmers should have sufficient fluid intake to prevent dehydration before/during training.

Table 2. Sweat loss, fluid intake and urine output during training

		Sweat loss (g)	Fluid intake volume (g)	Fluid intake frequency (times)	Fluid intake ratio (%)	Urine Volume (g)
Winter	Mean	855.6	523.3	9.1	47.9	251.0 *
	S.D.	417.8	294.9	4.3	22.6	207.2
Summer	Mean	1504.2 *	924.8 *	11.8	56.8	78.9
	S.D.	537.5	500.6	2.9	21.3	54.0

* $P < 0.05$

The relationship between fluid intake frequency and fluid intake volume during swimming training is shown in Fig. 2. The correlation coefficient was 0.501 in winter and 0.817 in summer ($P < 0.05$). This result suggests that increasing the frequency of fluid intake during swimming training is required, especially in summer.

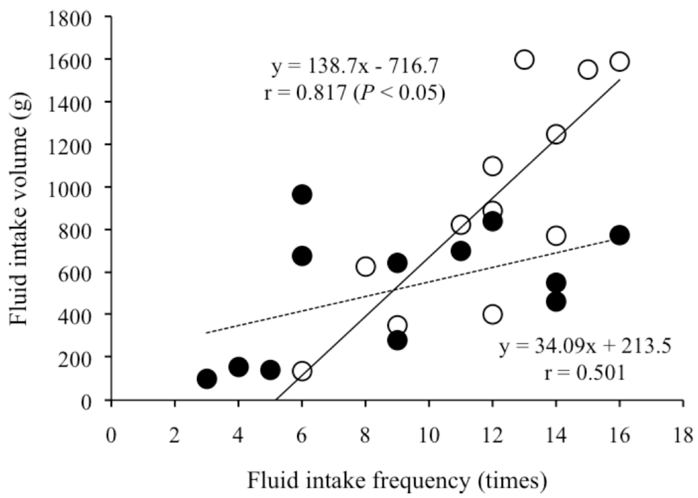


Figure 2. The relationship between fluid intake frequency and fluid intake volume during swimming training. Summer: open circle and solid line, Winter: closed circle and dotted line. There was a significant correlation coefficient in summer (r = 0.817, P < 0.05).

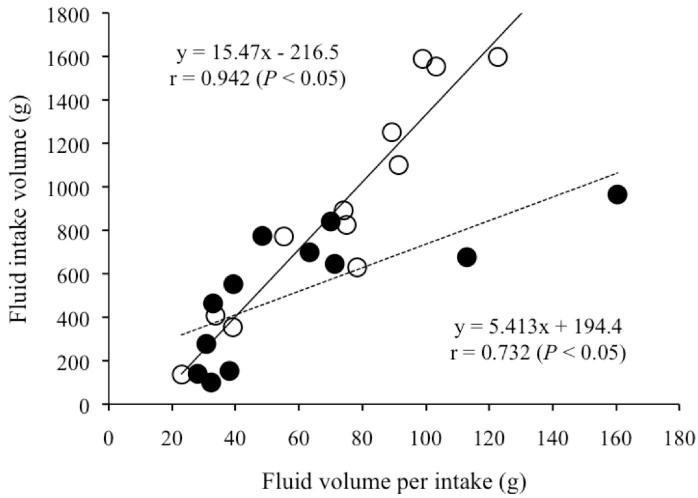


Figure 3. The relationship between fluid volume per intake and fluid intake volume during swimming training. Summer: open circle and solid line, Winter: closed circle and dotted line. There was a significant correlation coefficient in summer (r=0.942, P < 0.05) and winter (r=0.732 P < 0.05).

Figure 3 shows the relationship between fluid volume per intake and fluid intake volume during swimming training. There was a significant correlation coefficient in summer (r=0.942, $P < 0.05$) and winter (r=0.732 $P < 0.05$). This relationship indicated that increasing the volume of fluid per intake resulted in the sustaining of large fluid intake volume. There was no significant difference in the frequency of fluid intake between winter and summer (Table 2) because of swimmers are allowed to take fluid only in the interval time during swimming training.

The correlation coefficient between the amount of sweat loss and the volume of fluid intake was 0.262 in winter and 0.813 ($P < 0.05$) in summer. Maughan, R. J. *et al.* (3) reported that there was no apparent relationship between the amount of sweat loss and the volume of fluid consumed during soccer training in a cool environment. The relationship between the amount of sweat loss and the volume of fluid in this study is similar.

CONCLUSION

Sweat loss and fluid intake during swimming training was related to pool condition. However, there was no difference in the fluid intake ratio and the frequency of fluid intake between summer and winter. Because there is considerable variability in sweat loss and fluid intake between individuals, individualized fluid replacement program are recommended during training. It is considered that swimmers should have more fluid intake before/during swimming training to prevent dehydration, especially in summer.

REFERENCES

1. ACSM Position Stand (2007). Exercise and Fluid Replacement. *Med Sci Sports Exerc,* 39 (2): 377- 390.
2. Cox, G. R., E. M. Broad, M. D. Riley, and L. M. Burke (2002). Body mass changes and voluntary fluid intakes of elite level water polo players and swimmers. *J Sci Med Sport* 5: 183–193.
3. Maughan, R.J., S.M. Shirreffes, S.J. Merson and C.A. Horswill (2005). Fluid and electrolyte balance in elite male football (soccer) players training in a cool environment. *J Sports Sci*, 12(1): 16-31.
4. Robinson, S. and A. Somers (1971). Temperature Regulation in Swimming. *J Physiol Paris*, 63 : 406-409.
5. Taimura A., M. Yamauchi, E. Kaneda, and M. Sugahara (1995). Sweat loss and fluid intake during swimming exercise : A field study. In: T. Nagasaka and A.S. Milton (ed.). Body temperature and Metabolism, Tokyo, IPEC, 125-128.
6. Taimura A, Sugawara M. and Tsuchiya K. (1997). Influence of water temperature and swimming velocity on body temperature and weight loss during swimming. *Med Sci Sports Exerc* 32(5): s156.
7. Taimura, A., and M. Sugahara (1993). Weight loss and fluid intake during swimming exercise (in Japanese). *Jpn J Phys Fitness Sports Med*, 42(6): 775.

The effect of pool length on swimming intensity

Shiho Kurosaka[1], Yuuki Ono[1], Hisashi Furuta[2], Takashi Kurokawa[1]

[1]Hiroshima University, Graduate School of Education, Japan

[2]Saitama University, Faculty of Education, Japan

The influence of the pool length on physiological and perceptual effects was studied by comparing heart rate (HR), oxygen uptake ($\dot{V}o_2$), and rating of perceived exertion (RPE) while swimming at the same speed. Ten trained university swimmers swam the crawl stroke with 2 kinds of breathing pattern in lanes of fifty meters, twenty five meters, and fifteen meters. The $\dot{V}o_2$–HR relation was obtained during submaximal and maximal work in tethered crawl swimming. The result was that in the case of both normal breathing and controlled breathing, physiological exercise intensity (HR, $\dot{V}o_2$) and perceptual exercise intensity (RPE) significantly decreased with the decrease in the length of the swimming lane.

Key words: *HR, $\dot{V}o_2$, RPE, pool length, swimming*

INTRODUCTION

There are two kinds of official pools in swimming competition, 50 m and 25 m. Swimmers are usually trained in these two pools.

There have been several studies on the effect of pool surroundings on exercise intensity during swimming, for example on the effect of pool depth (Fukamachi, et al. 2004) and on the effect of water temperature (Costill, 1960). However, there have not been any studies on the effect of pool length. This study was designed to determine if pool length causes differences in the physiological intensity of exercise despite the same training menu and provide useful information for swimming training.

The purpose of this study is to examine the influence of the pool length on physiological and perceptual effects by comparing heart rate (HR), oxygen uptake ($\dot{V}o_2$), and rating of perceived exertion (RPE) while swimming at the same speed in swimming pools of different lengths.

METHODS

Ten swimmers (five male and five female) participated in the study. They belonged to a university swimming team and have trained for ten years or more. The average age, height, and weight for males was 21.6 yr, 171.7 cm, and 63.4 kg, respectively, and for females was 20.0 yr, 160.5 cm, and 56.5 kg, respectively.

1. Measurement of the $\dot{V}o_2$–HR relation in a tethered swimming tank

The $\dot{V}o_2$–HR relation was obtained during submaximal and maximal work in tethered crawl stroke, in order to correspond the heart rate in the swimming pool to $\dot{V}o_2$, before the experiment in the swimming pool. For this experiment the subject performed warm-up for 4 minutes after rest for 30 minutes, and work load was increased by 1 kg every two minutes until the subject reached exhaustion.

2. Experiment in the swimming pool

The subject swam using crawl stroke with the 2 kinds of breathing patterns: normal breathing and controlled breathing (i.e. breathing once every four arm cycles) in lanes of three different lengths (50 m, 25 m, and 15 m) which were set in an outdoor 50 m swimming pool. Each subject was requested to swim 300 m×3 times at three levels of exercise intensity i.e. RPE9 (very light), RPE13 (somewhat hard), and RPE17 (very hard) on Borg's RPE scale. This request is called objective RPE. Rest for five minutes was set between each trial. The executing order of each trial was at random, and were performed on different days whenever changing the pool length and the breathing pattern. Meteorological conditions were as follows, weather: fine ~ cloudy, water temperature: 27~32°C, ambient temperature: 27~33°C.

Subjects had a HR monitor attached (Accurex Plus, Polar Co.), and HR was measured every 5 seconds from the start to finish of each trial. The time for the 300 m swim was recorded, and the swimming speed was calculated by the distance divided by time.

3. Statistical analysis

Linear regression equations were obtained between the speed and HR, speed and $\dot{V}o_2$, and speed and RPE for each subject to calculate the HR, $\dot{V}o_2$, and RPE values at a speed of 1.2 m/s. Lane length (3; 50 m, 25 m, or 15 m) × breathing pattern (2; normal or controlled) analysis of variance (ANOVA) was used to determine the influence of the lane length and the breathing pattern on physiological and perceptual effects. Bonterroni's test was used as a further analysis, and the level of significance was set at p<.05.

RESULT

The relationship between the swimming speed and the HR for each subject with normal breathing in the 50 m lane is shown in Fig.1, and the relationship of the swimming speed and RPE in Fig.2. Both the HR and RPE increased linearly with increasing swimming speed, showing significant correlation for all subjects (in the case of HR: r=.945~.999, in the case of RPE: r=.904~.999). In the case of the 25 m and 15 m lanes, and for controlled breathing, similar results were obtained.

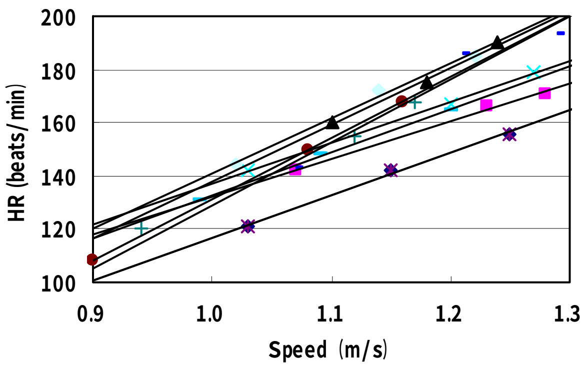


Fig.1 The relationship between swimming speed and HR for normal breathing in the 50 m lane.

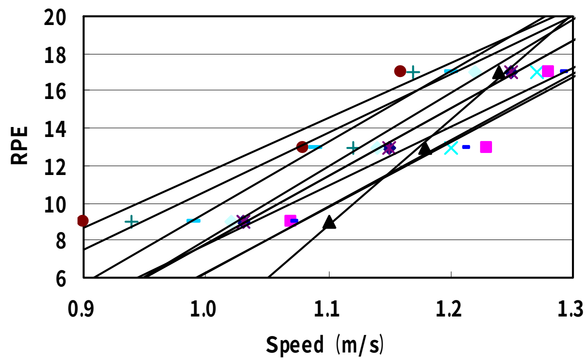


Fig.2 The relationship between swimming speed and RPE for normal breathing in the 50 m lane.

The mean HR values at a speed of 1.2 m/s are shown in Figure 3. In the case of normal breathing, HR decreased with the decrease in the length of the swimming lane. The HR in the 50 m lane (165±11.2 beats/min) was 5 beats/min higher than in the 25 m lane (160±10.7 beats/min), and 20 beats/min higher (p<.05) than in the 15 m lane (145±10.7 beats/min). In the case of controlled breathing, HR also decreased with the decrease in the length of the swimming lane. The HR in the 50 m lane (171±13.5 beats/min) was 9 beats/min higher than in the 25 m lane (162±12.7 beats/min), and 18 beats/min higher (p<.05) than in the 15 m lane (153±15.1 beats/min). The HR of controlled breathing in the 50 m lane was 6 beats/min higher, that in the 25 m lane was 2 beats/min higher, and that in the 15 m lane was 8 beats/min higher compared with those of normal breathing, respectively.

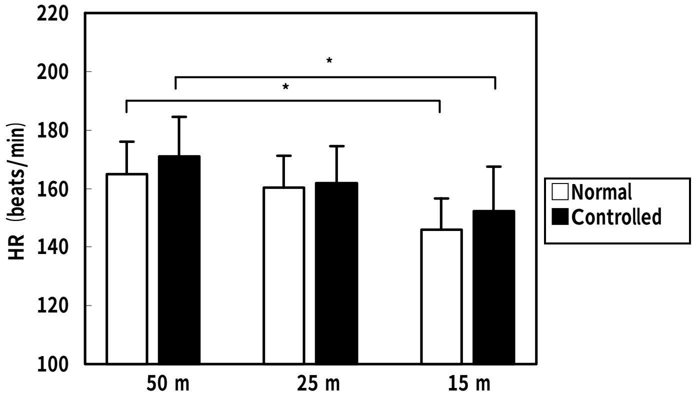


Fig.3 HR at a speed of 1.2 m/s. (*p<.05)

The mean $\%\dot{V}o_{2max}$ values at a speed of 1.2 m/s are shown in Figure 4. In the case of normal breathing, $\%\dot{V}o_{2max}$ decreased with the decrease in the length of the swimming lane. The $\%\dot{V}o_{2max}$ in the 50 m lane (89.9±7.7%) was 5.8% higher than in the 25 m lane (84.0±9.6%), and 20.7% higher ($p<.05$) than in the 15 m lane (69.2±9.2%). In the case of controlled breathing, $\%\dot{V}o_{2max}$ also decreased with the decrease in the length of the swimming lane. The $\%\dot{V}o_{2max}$ in the 50 m lane (94.0±10.6%) was 5.8% higher than in the 25 m lane (87.2±9.2%), and 10.2% higher ($p<.05$) than in the 15 m lane (82.8±10.4%). The $\%\dot{V}o_{2max}$ of controlled breathing in the 50 m lane was 4.1% higher, that in the 25 m lane was 3.2% higher, and that in the 15 m lane was 13.6%, which was significantly higher compared with those of normal breathing, respectively.

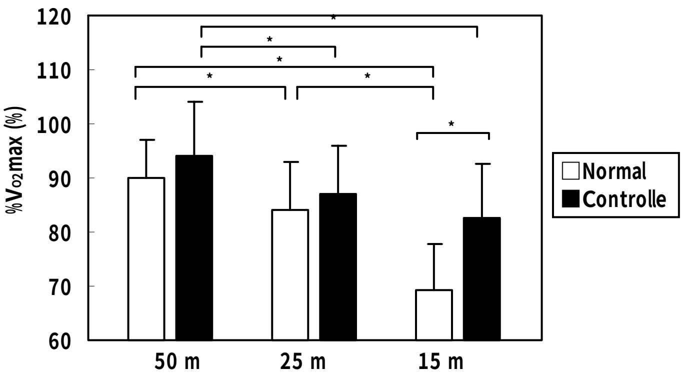


Fig.4 $\%Vo_2max$ at a speed of 1.2 m/s. (*p<.05)

The mean RPE values at a speed of 1.2 m/s are shown in Figure 5. In the case of normal breathing, RPE decreased with the decrease in the length of the swimming lane. The RPE in the 50 m lane (15.1±1.35) was 1.9 levels higher than in the 25 m lane (13.2±2.04) and significantly higher ($p<.05$) by 4.3 levels than in the 15 m lane (10.8±2.97). In the case of controlled breathing, RPE also decreased with the decrease in the length of the swimming lane. The RPE in the 50 m lane (15.1±2.11) was 0.2 levels higher than in the 25 m lane (15.3±2.47) and 2.8 levels higher than in the 15 m lane (12.7±2.36). The RPE of controlled breathing in the 50 m lane was 0.4 levels higher, that in the 25 m lane was significantly higher ($p<.05$) by 2.1 levels, and that in the 15 m lane was significantly higher ($p<.05$) by 1.9 levels compared with those of normal breathing, respectively.

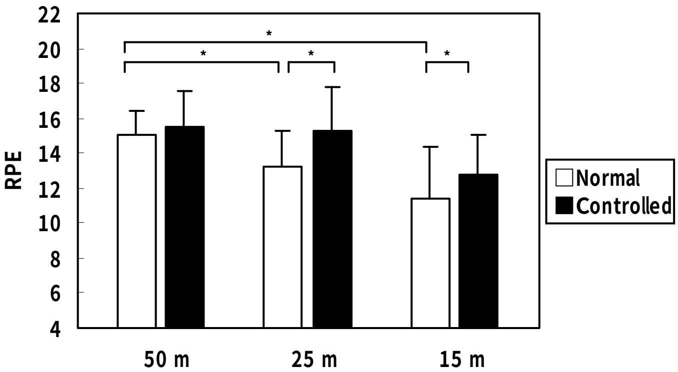


Fig.5 RPE at a speed of 1.2 m/s. (*p<.05)

DISCUTTION

1. The validity of HR and RPE

This study used Borg's RPE scale as an index of perceptual exercise intensity, and HR and $\dot{V}o_2$ as indexes of physiological exercise. This RPE scale was devised as ten times RPE corresponding to the HR value. The HR in this study also increased with the increase of the objective RPE. However the HR value did not always correspond to the objective RPE. That is, HR was 30-40 beats/min higher than the objective RPE9, 15-20 beats/min higher than the objective RPE13, and almost corresponded to RPE17. Kurokawa & Ueda (1992) proved that HR corresponded to RPE at high exercise intensity in trained swimmers, while the HR is higher than the RPE at low to middle exercise intensity. Because lower blood lactate concentrations develop during exercise in trained limbs (Klausen, et al. 1972; Ridge, et al. 1976), it would be expected that RPE would be higher at a given HR in trained subjects.

2. The influence of pool length on physiological and perceptual indexes

HR and $\%\dot{V}o_{2max}$ decreased with the decrease in the length of the swimming lane at the same speed of 1.2 m/s. This result means that physiological exercise intensity and energy consumption decreased with the decrease in the length of the swimming lane even if swimming at same speed. This seems to be influenced by the turn. The turn can stop the movement of a stroke and remain the swimming speed with decreasing energy consumption (Maglischo, 2003). In this study, the frequency of turns increased in ascending order of 50 m (5 times), 25 m (11 times), and 15 m (19 times).

The RPE at the same speed also decreased with the decrease in the length of the swimming lane. This seems not to be due to perceptual reasons but due to physiological reasons. If physiological indexes such as HR and $\%\dot{V}o_{2max}$ were equal in the three lanes and the difference of RPE still occurred, it was considered to be due to the effect of perceptual load. However in this study, it was because there were differences between the three lanes in HR and $\%\dot{V}o_{2max}$, and the RPE also changed corresponding to these differences.

CONCLUSION

In the case of both the normal breathing and the controlled breathing, physiological exercise intensity (HR, $\dot{V}o_2$), and perceptual exercise intensity (RPE) decreased significantly with the decrease in the length of the swimming lane.

REFERENCES

1. Klausen K, Rasmussen B, Clausen J P, Jensen J (1972) Blood lactate from extremities before and after arm or leg training. Am J Physiol, 227：67-72

2. Kurokawa T, Ueda T (1992) Validity of ratings of perceived exertion as an index of exercise intensity in swimming training. Ann Physiol Anthrop, 11 : 277-288

3. Maglischo E W (2003) Swimming fastest. Human Kinetics : Michigan,　pp.287-294

Testing motor ability of children related to aquatic space activity – a proposition

Bodo E Ungerechts[1]

[1] University Bielefeld, Department of Neurocognition and Action-Biomechanics, Germany

Aquatic space activities are attractive for humans from childhood on. Society of some countries decided that each child had to follow swimming lessons in elementary classes educated by teachers after an appropriate qualification by university. The education of instructors is world wide somewhat different. In each case, parents or society expect at the end of a course that children can master aquatic space activities safely and being able to stay in water joyfully. The purpose of this paper is a report on a study about the motor ability of 1340 children related to aquatic space activity, called Motoric Basic Qualifications, in a county where swimming lessons are obligatory for each pupil.

Keywords: *swimming lessons, children, motoric basic qualifications*

INTRODUCTION

Teaching children how to swim is a world wide task. Teaching swimming will be executed by parents, school teachers or instructors in swimming clubs. Very rarely children learn to swim at their own although this is not impossible. There is a broad social conscience that the children should learn to swim mainly for two reasons: to save their lives and to be able to participate in more areas of life (in some societies at least). Based on experience the best age learning swimming is about 6 – 8 years when children go to primary school. In some countries these primary schools are obliged to teach swimming.

One major question is “What is the best method to teach swimming?” In former times there was a strong belief that a person is able to swim as soon he/she can execute the technique properly. Consequently, drills have been practiced on land and then the person was ordered to enter aquatic space. According to later concept pupils entered aquatic space and were carried by means of a fishing rod while executing technical drills. When the instructor was convinced that the pupil could do without the fishing rod it was put aside.

Meanwhile experts are convinced that the follow steps are essential to enable pupils are to master swimming; the steps could be characterized by the following headings like (1) getting acquainted to the water, (2) floating, (3) breathing, (4) gliding, (5) kicking and (6) skin diving. In some parts of the world the following new concept is developed:

• Getting adapted to the properties of wet water masses
• Acquiring skills to manipulate the water mass and building up a concept of water mass in motion
• Learning a stable form of locomotion, mostly related to known swimming strokes.

According to the last concept knowledge is essential concerning how to manipulate water mass by actions of hands, feet or body.

Parents normally do not follow a tight time frame when helping their children to learn to swim. In schools or clubs the total number of teaching lessons is often related to some external time frame which mostly does not fit with the developmental needs of individuals learning swimming. To compensate this, schools and club are introducing signs of gratitude to motivate and to test the achievements.

Diploma for children are named frog, shark, sea horse or dolphin (the order is not important). Most schools teachers think that e.g. jumping into water, swimming a 25 m distance and fetching an object from a 1.2 m depth which is tested after 12 – 15 lessons is enough to judge if a child "can swim safely". An overwhelming part of club instructors belong also to this group. However, most of these children are not safe swimmers after passing these tests. Although children's static buoyancy is favourable (besides few exceptions) because the total density of children is above the density of the water which provides them from sinking to the ground, a major problem for beginners is: not to know how to breath or to hold breath while in water or how to react / act when the head is suddenly submerged shortly.

This paper is concentrating on the question "How to test the swimming ability of children?

METHOD

In Germany, a widespread study concerning the swimming ability of children aged 10 to 11 years old was executed. Experts have been asked which tests would be relevant to check "Who is a safe child swimmer?" To answer the question the experts decided not to consider the quality of technique or the amount of lanes a child is able to swim.

They discussed the aims of education of acquiring certain skill during childhood. Learning swimming does not mean necessarily to become a competitive swimmer. However, a more mutual aim could be: participation; to be able to participate in various areas of movement, leisure activities and sportive activities. In this context “being able to swim” is contributing to stronger self-esteem, to participate in much more corporal activities, to meet aspects of staying healthy or to recover over the whole lifespan. Last but not least the aim is the protection from drowning. Testing the swimming ability: experts have been asked to give practical examples of motoric basic qualification of aquatic space beyond aspects, like swimming fast or demonstrating a perfect technique. It is not to say that swimming fast or demonstrating a perfect technique are irrelevant items but after swimming lessons it is more relevant what children basically need to go swimming at their own and what can be expected. The experts established the following five tests as Motoric Basis Qualifications in Swimming without any distinction:

1. Jump into the water Qualification: Jump into the water from a starting block and swim back to the pool deck

2. 25 m Swimming Qualification: Cover a distance as well in prone as in back position

3. “Jelly fish position” Qualification: Float in jelly fish position next to water line and breath out air so that the body starts sinking

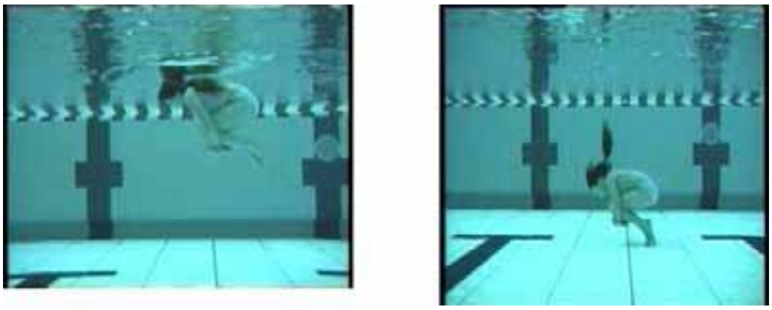
4. Gliding Qualification: Push off from the wall an glide 1.5 times body length

5. Slalom skin diving Qualification: Skin diving following a path of lemniscates.

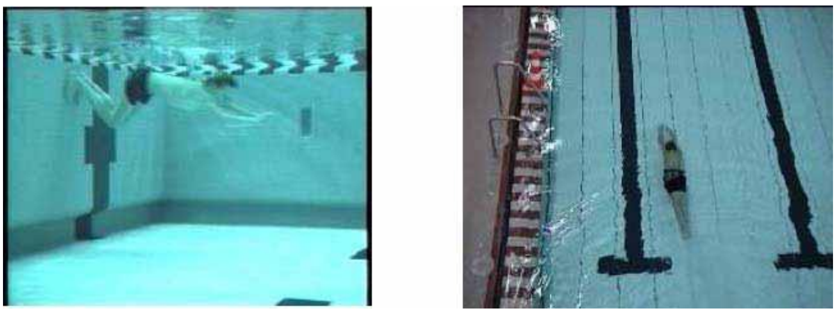
In a county wide investigation 1340 German pupils, aged 10 – 11 years, took part in the study of Motoric Basis Qualification -Swimming. They are representative for 180.000 pupils of the county. All pupils had swimming lessons at school in a period of 20 weeks and 90 min per week according to the official curricular of that county (Kurz et al, 2007).

(1) Jump into the water from a starting block and return to the pool side

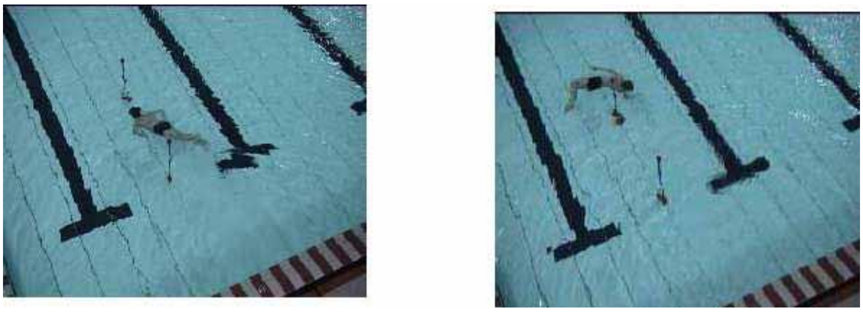
(2) Swimming 25 m, changing body position



(3) “Jelly fish position”, start form waterline and breath out



(4) Gliding



(5) Slalom skin diving

The pupils were tested according to a test-protocol, called Motoric Basic Qualifications, proposed by experts in swimming (working as instructors themselves and being known for their contributions in this area).

RESULTS

The results were as follows

Item	passed [%]	failed [%]
1. jumping into the water	87	13
2. swimming	81	19
3. jelly fish position	58	42
4. Gliding	66	34
5. Slalom skin diving	55	45

30 % of all pupils were able to master all five tests and 9 % of all pupils were not able to master any of the tests. 42% of all pupils were able to master three or four tests, including swimming a 25 m distance. Amazingly 19 % of the pupils were not able to swim 25 m partly in back and partly in prone position. 19 % of all pupils were able to master one or two of the tests, mostly jumping but not always swimming 25 m. 28 % of the pupils who could not master one or two tests were raised in families, which did not show significant interest for sportive activity; none of the family members tried to give swim lessons or did sent their children to swim lessons. However, without substantial family support during childhood it is nearly impossible to learn swimming in that age.

DISCUSSION

In a certain sense activities in aquatic space is more than acting physically in water. Activities in aquatic space is also dealing with the self, the own body and the interaction with others. Versatility is highly recommended: swimming alone and with others, skin diving, plunging and playing. This includes that people exchange sensitivity, understand

and apply rules, detect and understand bodily reactions, learn to feel reaction of water mass set in motion, get an idea about the variety of action concepts and responsibility for other by being prepared to rescue.

If “ability to act” is the centre of school education in sports than diversity and multi-mind are key words and the notion “Aquatic Space Activity” is a consequence, because it is more than swimming lanes. Activities in this space are not commutable experiences and therefore unique. In this context exact measurements of performance not useful. The pedagogical significance is to assist children unlock this space. However, most challenging is that swimming lessons at schools are hampered by logistic aspects to reach the pool and problems working indoors with too large groups. In addition the education of the “instructors” was once in former times more intensive. Education in sports suffers meanwhile from the fact that universities seems not so much to be interested any more in methodological research of sportive activities.

Besides the aspect to be a save swimmer the aspect of self-propulsion is an essential skill to be a “full” swimmer. From a biomechanical point of view there are several solutions to propel the body. In order to propel the body efficiently the number of solutions to move the arms and legs are limited. Based on a concept to analyse human movement, called Functional Movement Analysis, according to which each action (as part of a movement) serves a purpose or function all swimming strokes were re-evaluated by Ungerechts, Volck & Freitag (2002). In aquatic space the search of relevant functions is connected to flow physics and to energy supply aspects. It was found that in all strokes process same actions and functions. These mutual features are called Structural Affinities and are visualised by still pictures are giving a clue what all strokes have in common.

Structural affinities of strokes

• first fetch (slight finger-spreading) than catch(create suction on the back of the hand)

• elbow of the extended arm is facing oblique upwards

• turn-around action before slight elbow bending

•below waterline hands are leading the action

• rotate body: let trunk muscles do the work

Structural affinities of strokes

• elbow extension in combination with
“slicing“ action of the hand

• recover arm/hand not far from the body

•entering water in shoulder-width,
raising the shoulder (makes you longer)

Finally it is interesting to discuss in which way the knowledge and content of the above mentioned features can be distributed. Sengoku et al (2003) proposed internet utilisation which enables the instructors and pupils to acquire a multitude of resources for learning. They authors investigated the acceptance of Computer Assisted Instruction web site including multimedia contents by swimming classes (the pupils were used to Internet utilisation). The study revealed that pupils judged the use of this internet approach as easy. The usefulness was in favour of multimedia contents compared to written contents. They were able to filter out the information they need on individual basis. It was suggested that the pupils’ enjoyment in swimming increased by internet support. In a later study Senguko & Nomura (2006) demonstrated that pupils were able to achieve self selected aims by the use of Computer Assisted Instruction web site. In addition higher development was demonstrated in swimming performance for those pupils who used internet more intensively.

In consequence, society decided to give special courses to about 50 % of the present growing pupils. Some public moves are still necessary, namely to convince society to better the situation: more pools and educating instructors / teachers according to modern knowledge about teaching swimming.

REFERENCES

1. Kurz, D. & Fritz, T. (2007). Die Schwimmfähigkeit der Elfjährigen -Ergebnisse einer empirischen Studie in Nordrhein-Westfalen. Schule NRW. Amtsblatt des Ministeriums für Schule und Weiterbildung 59 (4), 188-191.

2. Senguko Y., Ichikawa H., Nomura T. (2003). Effect of different computer assisted instruction web site contents on swimming instructions of elementary school children. In: J C Chartard (ed.) Swimming IX. University of St. Etienne, 592-596.

3. Senguko Y., Nomura T. (2006). Effect of different computer assisted instruction web site for swimming to children's learning motives and learning strategy. In: J.P. Vilas-Boas, F. Alves, A. Marques (eds.) Biomechanics and Medicine in Swimming X, Portuguese Journal of Sport Sciences, Vol 6, Suppl 2, 341-343.

The role of lifesaving near a waterside

Yuumi Inagaki[1], Tsutomu Komine[1], Toshiharu Yamamoto[2]

[1]Ryutsu Keizai University, Faculty of Health & Sport Sciences, Japan

[2]International Budo University, Faculty of Physical Education, Japan

The number of people who do not know how to play safety in the beach becomes larger and who could not protect by themselves increases, because people become less involved with the beach due to the changes of an environment and a lifestyle in resent years. Therefore, it would be seen that the role which lifesaving should carry out near a waterside is large if we think about the role of lifesaving including the rescue practice. It is as a natural that lifesavers are able to do the primary lifesaving measures, it has been asked whether, besides, they could prevent accidents and keep the smile of people. In order that, the consciousness must be changed from saving to protecting, then we should reaffirm that it is a prevention that is the best rescue, and practice the active lifesaving.

Key words: *lifesaving, prevention of accidents, safety education, rescue*

INTRODUCTION

Our country is surrounded by sea, and its citizens have walked every direction with the sea. The sea is right water itself, and it can be stated that human life originated in the water. However, in the present situation, a connection between the seaside and people has become narrow as a result of the sudden change in the environment and lifestyle. People are moving away from the sea, and opportunities to closely explore the natural water are decreasing. Therefore, the number of people who are unaware of playing safely on the beach and are unable to protect their own lives is on the rise. In view of this, I suggest that spreading the awareness of safety around a body of water as well as ensuring the prevention of accidents along a waterside—called lifesaving—and practicing the monitor/rescue activity in the area, should be considered important. Besides, it is essential to have lifesavers who give primary importance to the prevention of accidents, and moreover, rescue quickly and safely, and perform the primary lifesaving measures or first aid when an accident occurs. Hence, I consider the role of lifesaving as the rescue along a waterside, which is what lifesavers actually do.

Lifesaving in Japan

The activities of the Japan Lifesaving Association (JLA)—one of the private organizations— is in the forefront of life saving in Japan. JLA is positioned as a Japanese representative organization of the International Lifesaving Federation (ILS), which is an international organization for lifesaving. Its activities can be summarized in the following keywords: lifesaving, sports, education, environment, and welfare (Figure 1), and contributes to the spread of awareness on the prevention of accidents and dignity of life.

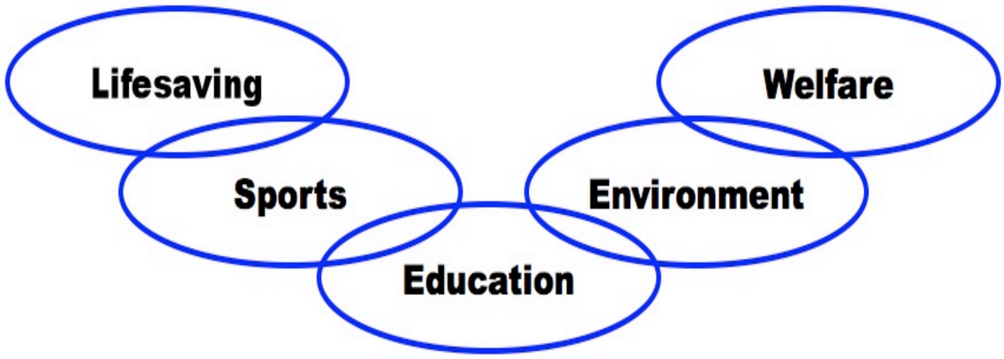


Figure 1. The activity of the JLA

JLA conducts investigations on water accidents on the beach during the summer season on a national scale. According to the report of the JLA in 2005, the number of beaches in which JLA conducted investigations was 184, and there were 386 reports from 73 beaches. On the basis of age, the number of rescues was the largest at 22.1% among 20–24 year olds, followed by 21.5% among 5–9 year olds, and 14.3% among 10–14 year olds (Table 1 and Figure 2). It is to be noted that there are two peaks between the percentage of 5–14 year olds (primary and junior high school students) and one for the percentage of the youth in their early 20s. This implies that the number of rescues of children and the youth on the beach is considerably high. The key to prevent such large incidents could be lifesaving. We could provide education on the safety and prevention of accidents to primary and junior high school students, and teach the techniques for rescue and explain their importance of them to the youth. From these programs, an effective prevention of accidents could be possible.

Table 1. The number of rescues (JLA, 2005) on the basis of age

	0-4 years	5-9 years	10-14 years	15-19 years	20-24 years	25-29 years	30-34 years	35-39 years	40-44 years	45-49 years	50-54 years	55-59 years	over 60	Total
Frequency	15	75	50	39	77	23	17	15	17	5	3	3	10	349
%	4.3	21.5	14.3	11.2	22.1	6.6	4.9	4.3	4.9	1.4	0.9	0.9	2.9	100

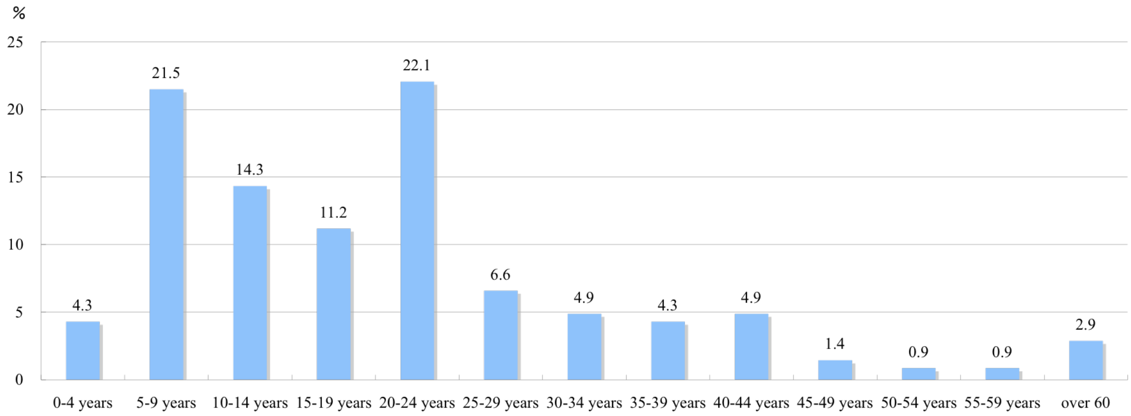


Figure 2. The number of rescues (JLA, 2005) on the basis of age

An example of the development of lifesaving

To develop lifesaving, I would like to suggest three stages as shown in Figure 3. In stage 1, we enjoy the sea and water. Enjoying nature is the best incentive to prevent an accident. In stage 2, we could explore ways of rescuing oneself, which is the concept of "self-rescue." It is very difficult to save a person unless you could protect yourself. In stage 3, we are aware rescuing others' lives, and we could learn the value and the importance of a life through the actual rescue techniques. Lifesaving entails enjoying nature and protecting oneself through the contact with water and people; moreover, it hides the possibility pondering about saving lives and dignity of the life.

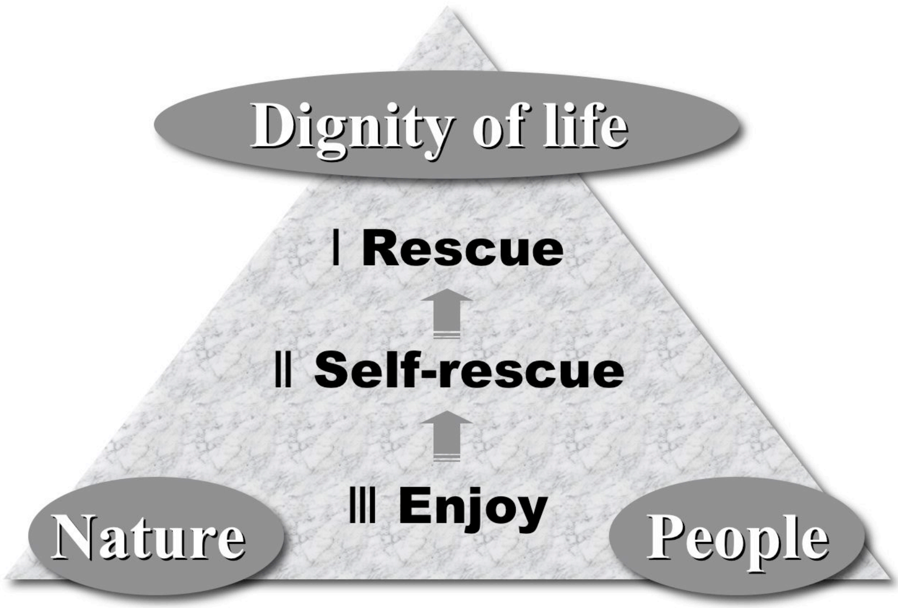


Figure 3. Three stages to develop lifesaving

Actual rescue

Before going to rescue

The mission of the lifesaver is to prevent an accident. However, he/she conducts a rescue when an accident occurs. The technique to rescue drowning people is important; however the prevention of an accident is more important. Hence, safety is always given priority. Therefore, before attempting a rescue action, he/she should grasp the situation and select a certain rescue technique. It is necessary to be aware of the items mentioned below for a safe, certain, and quick rescue.

- the knowledge of the procedure of using rescue equipments
- the technique to enable the rescue by the method that was selected by the lifesaver
- the physical strength required for the rescue
- a judgment based on knowledge, technique, and physical strength
- the discipline to accept precisely the important instructions of a patrol captain and self-management
- the instinct to use necessary equipments and techniques effectively in case of a change in the situation

Sometimes a rescuer faces the task of rescuing alone, and sometimes rescuers conduct rescues in a team. Practicing rescue technique many times by considering various rescue scenarios enables us to lower stress and remain calm so as to enable us to select a rescue technique in an actual rescue. In the course of the rescue, there is always a danger to the rescuer. It is recommended that we do our best to prevent the occurrence of a second accident, and ensure that the equipments are put to practical use; moreover, we should prepare a backup system with the cooperation of others even if it seems to be an easy rescue.

The principles of rescue

A rescuer is taught to follow the following three principles (Figure 4) in order to conduct a safe, certain, and quick rescue.

- safety: to ensure the safety of the rescuer and patient
- certainty: to select a certain way of rescue
- quickness: to rescue quickly

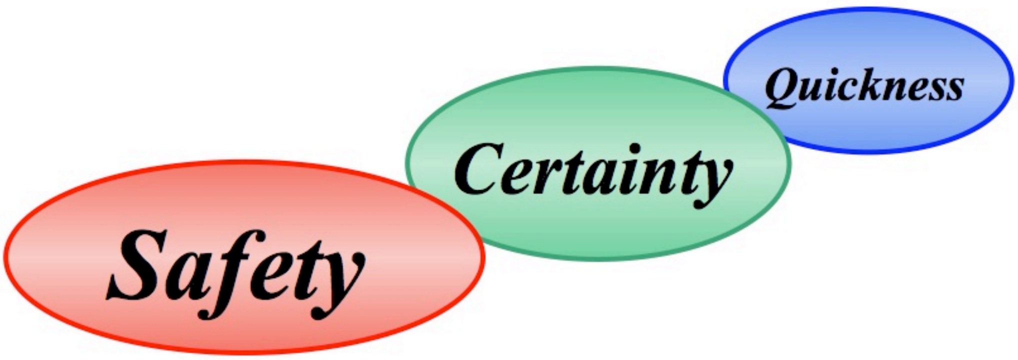


Figure 4. The principles of rescue

Selecting the rescue method

After judging the situation, the rescuer should select a rescue technique according to the situation in which the victim is discovered, in reference to the items in Table 5.

Table 5. Selection of rescue techniques based on the criteria

1	**the condition of patient**	→one or many patients? →conscious or unconscious?
2	**the position of patient**	→near or far?
3	**the condition of sea**	→is there a surf? →how is the current? →deep or shallow? →are there rocks or coral?
4	**the assistant**	→is there a rescuer besides yourself?
5	**the rescue equipment**	→what kind of rescue equipment do you have? →If there is no rescue equipment, is there any useful thing like a float?
6	**the change of situation**	→the situation around the patient gradually changes even if you gauge the situation or attempt the rescue. Hence, you should maintain flexibility and grasp the changing situation.

CONCLUSION

With regard to the prevention of accidents by lifesaving, it may be a short-term effect to learn risk management technique and practice it. In short, we should take measures to prevent an accident, and prepare the knowledge and technique of a practical rescue if an accident occurs. However, this has a limitation. Only a lifeguard or a manager has the huge responsibility of protecting lives on the spot. Therefore, I would like to state that by spreading the awareness of lifesaving to the society, we can encourage everyone to become lifesavers, that is, become the people who assure security, are the personification of real safety and security. Lifesaving can be considered as the greatest vaccine to prevent accidents. Our society would become safer if adults acquire the rescue techniques and become aware of the importance of preventing accidents; moreover, it may create opportunities to ponder on the dignity of life, such as its value, its importance, and be sympathetic—values that are decreasing among children. The role of lifesaving along a waterside is huge. Practicing the primary lifesaving measures should come naturally to people; moreover, we have been asked if we could prevent accidents and maintain the smiles of people. For this, I believe that we should shift our focus from saving to protecting, reaffirm that prevention of accidents is the best form of rescue, and practice active lifesaving.

Oral presentation

Day 3 – 27th March

<u>Room 1</u> - (Hole 200)

Effect of velocity increase on arm coordination, active drag and intra-cyclic velocity variations in front crawl

Seifert L.[1], Toussaint H.[2], Schnitzler C.[1], Alberty M.[3], Chavallard F.[1], Lemaitre F.[1], Vantorre J.[1], Chollet D.[1]

[1] CETAPS EA 3832, Faculty of Sports Sciences, University of Rouen, France

[2] Institute of Fundamental and Clinical Human Movement Sciences, Free University, Amsterdam, The Netherlands

[3] LEMH EA 3608, Faculty of Sports Sciences, University of Lille, France

The effect of velocity increase on index of arm coordination (IdC), active drag (D) and intra-cyclic velocity variations (IVV) in front crawl swimming was analysed. 12 national level swimmers performed an intermittent graded pace test on the MAD-system and in the free condition, swimming arms only. Drag was determined using the MAD-system. V, the duration of the entry, pull, push, recovery and IdC were calculated from underwater and aerial side view video recordings. The hip IVV was analysed using a velocity-meter. The increase in V was associated with increases in pull, push and recovery phases, IdC and D, decreases in entry phase and a non significant change of IVV. The change in IdC with V followed those in D with V ($D=27.02V^{2.25}$, $IdC=44.70V^2-81.42V+19.02$) indicating that swimmers shifted from the catch-up to the opposition coordination to overcome the active drag, when swimming at a higher velocity. The adaptation of the motor organisation appeared adequate because it did not lead to greater IVV.

Key words: *biomechanics, motor control, coordination, drag, velocity variation*

INTRODUCTION

Swimming performance was regularly assessed by the changes of stroking parameters (velocity, stroke rate and stroke length), without explaining the motor organisation (Craig & Pendergast, 1979). Using an index of coordination (IdC), which quantifies the lag time between propulsive actions of both two arms, Chollet et al. (2000) have proposed a method to assess the arm stroke phase organisation in front crawl stroke. When the swimming velocity increased from low to fast paces, IdC and the stroke rate increased while the stroke length decreased (Chollet et al., 2000; Seifert et al., 2007), showing a shifting from a catch-up to a relative superposition coordination mode. Seifert et al. (2007) postulated that the increase of the environmental constraints, notably active drag, would necessitate the increase of IdC. In fact, above a critical velocity (1.8 $m.s^{-1}$) (Toussaint & Truijens, 2005) and stroke rate (50 $stroke.min^{-1}$) (Potdevin et al., 2006; Seifert et al., 2007), the superposition mode occurred as the main motor solution to overcome the high active drag (that increase with velocity squared). Conjointly, intra-cyclic velocity variation (IVV) appeared as an interesting parameter of propulsive efficiency. Notably, Barbosa et al. (2006) showed a positive correlation between IVV and energetic cost. The present study aimed at analysing the effect of the increase in swimming velocity on arm coordination alongside active drag (D) and IVV in front crawl stroke. It was hypothesized that the change of coordination followed the drag increase while IVV remained constant, suggesting an appropriate arm coordination at each velocity.

METHODS

12 French national level male swimmers were volunteered for this study. The mean ± SD age, body mass and height of the subjects were: 20.5 ± 2.1 years, 75.2 ± 7.2 kg, 181 ± 7 cm respectively. At the moment of the experimentation, they trained 13.2±5.3 hours per week, and had 10.5 ± 3.2 years of practice. Their mean performance in for the 100-m front crawl long pool was 55.2 ± 2.7 s which corresponds to 84.0 ± 4.2% of the 2007 world record.

In a randomized order, swimmers performed two intermittent graded pace tests in arms only front crawl stroke (swimmers wore a pull-buoy): one swam on the MAD-system (10 stages of 25-m), and one in free condition (8 stages of 25-m, from the 3000-m pace to their maximal velocity). Four minutes of rest was accorded between each stage.

Free graded paced test

In the free swimming condition swimmers were filmed using two underwater video cameras (Sony compact FCB-EX10L, sample rate of 50Hz); one placed to obtain a frontal view and the other to obtain side view. Both cameras were connected to a double-entry audio-visual mixer, a video timer, a video recorder and a monitoring screen to mix and genlock the frontal and side views on the same screen. A third camera mixed with the side view for time synchronisation, video-taped all trials with a profile view from above the pool. From the side views the mean stroke rate (SR in $cycle.min^{-1}$)

was calculated. The third camera measured the time over a 12.5-m distance (from 10-m to 22.5-m) to obtain the swimming velocity (V in $m.s^{-1}$). Stroke length (SL in $m.cycle^{-1}$) was calculated from the mean V and SR values: SL = V*60/SR.

Arm coordination was assessed by the index of coordination (IdC) (Chollet et al. 2000). Two operators analysed the key points of each arm phase with a blind technique, i.e. without knowing the analyses of the other operator. The four arm stroke phases (in % of the stroke cycle duration) were the entry and catch of the hand in the water, the pull, the push and the recovery (Chollet et al., 2000). The IdC is defined as the time gap between the beginning of propulsion in the first right arm stroke and the end of propulsion in the first left arm stroke, and between the beginning of propulsion in the second left arm stroke and the end of propulsion in the first right arm stroke (Chollet et al., 2000). The average IdC was calculated for the three complete strokes taken in the 12.5-m central part of each 25-m stage. IdC was expressed as a percentage of the mean duration of the stroke. When a lag time occurred between the propulsive phases of the two arms, the stroke coordination was called 'catch-up' (IdC < 0%). When the propulsive phase of one arm started when the other arm ended its propulsive phase, the coordination was called 'opposition' (IdC = 0%). When the propulsive phases of the two arms overlapped, the coordination was called 'superposition' (IdC > 0%).

The hip intra-cyclic velocity variation (IVV) was also assessed from the test in the free condition. The underwater side view was synchronised with a velocity-meter (Fahnemann 12® 045, Bockenheim, Germany). The swimmers were connected to an unstretchable cable driving an electromagnetic angular velocity tachometer. The measurements were taken using 30 meters of stainless steel light cable coiled around the tachometer and connected at the distal end to a harness belt attached to the swimmer's waist. It provided a linear velocity measurement of the hip and was relayed into a computer. For each subject, the three complete strokes of the 12.5-m central part were averaged. The corresponding time-velocity curves were smoothed (6 Hz) by Fourier analysis. The IVV was analysed by calculating its coefficient of variation (CV) obtained by the ratio of the standard deviation (SD) and the average (Mean) values of the velocity signal: CV=Mean/SD.

Graded pace test on Mad System

For this graded paced test, the swimmers swam on the MAD-system. The MAD-system allows the swimmer to push off from fixed pads with each stroke. These push-off pads are attached to a 22 m long rod. The distance between the push-off pads can be adjusted (normally 1.35 m). The rod is mounted ± 0.8 m below the water surface. The rod is connected to a force transducer enabling direct measurement of push-off forces for each stroke. Subjects use only their arms for propulsion; their legs are floated with a pull-buoy. If a constant swimming speed is maintained, the mean propelling force equals the mean drag force (D in N). Hence, swimming one lap on the system yields one data-point for the speed-drag curve (Fig. 1) (Toussaint & Truijens, 2005).

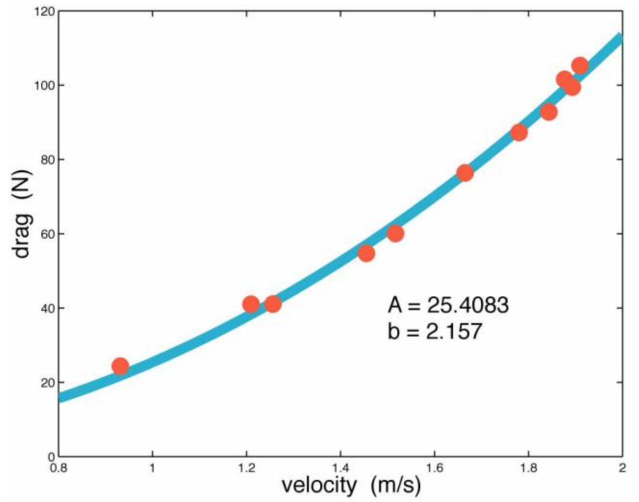


Figure 1. Example of D-V curve from MAD-system measurement

One-way ANOVA analysed the effect of graded pace on the stroking parameters (V, SR, SL, CV), on index of coordination and arm stroke phases. Then, the relationships between V and D, V and IdC, V and IVV were assessed.

RESULTS AND DISCUSSION

The present study is a first attempt to link motor organisation variables, such as IdC, to kinematical and kinetic parameters, throught the analysis of IVV and swimming velocity-drag relationship.

The changes of the parameters in the free condition are reported in Tables 1 and 2. The results were in line with previous observations i.e. the increase in V was associated with a significant increases in SR with a significant (but relatively smaller) decrease in SL ($p<0.05$). The temporal organisation of the stroke cycle was modified. As the swimming velocity increased, the swimmers favoured the time dedicated to propulsion (pull + push phases) within the stroke cycle. The IdC value increased which implies a better chain of consecutive propulsive actions of both arms. The observed increase in SR was made at by shortening the duration of the catch-phase thus at the expense of the non-propulsive underwater phase (Chollet et al., 2000; Seifert et al., 2004; Seifert et al., 2007).

Table 1. Changes of stroking parameters with the increase of pace during the free graded pace test (swimming arms only)

Paces	V ($m.s^{-1}$)		CV (-)		SR ($cycle.min^{-1}$)		SL ($m.cycle^{-1}$)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
3000-m	0.90	0.07	0.15	0.02	24.8	1.7	2.17	0.17
1500-m	1.03	0.09	0.14	0.01	28.4	2.0	2.18	0.18
800-m	1.10	0.11	0.15	0.02	30.0	2.2	2.20	0.26
400-m	1.19	0.10	0.14	0.02	36.9	5.2	1.95	0.15
200-m	1.32	0.09	0.13	0.02	43.9	6.0	1.82	0.18
100-m	1.37	0.09	0.13	0.03	48.8	6.0	1.69	0.16
50-m	1.45	0.07	0.15	0.03	56.5	3.7	1.54	0.10
Vmax	1.47	0.07	0.13	0.04	59.8	3.8	1.47	0.11

Table 2. Changes of IdC and arm stroke phases with the increase of pace during the free graded pace test (swimming arms only)

Paces	IdC (%)		Catch (%)		Pull (%)		Push (%)		Recovery (%)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
3000-m	-18.3	2.5	43.9	2.6	13.4	1.8	18.0	2.0	24.6	3.5
1500-m	-17.5	2.4	42.9	2.8	14.1	1.2	18.4	1.6	24.6	3.0
800-m	-15.7	2.5	42.8	3.4	14.4	1.0	19.0	1.4	23.7	3.1
400-m	-13.9	2.6	38.3	3.9	15.6	2.1	20.6	1.2	25.5	2.8
200-m	-11.0	3.8	34.9	4.8	16.2	2.1	22.9	3.1	26.0	2.6
100-m	-8.2	2.7	31.5	4.6	18.6	2.0	23.1	2.2	26.9	2.7
50-m	-5.2	3.3	27.0	3.9	20.2	2.4	24.5	2.4	28.4	2.4
Vmax	-3.9	2.1	25.9	3.4	21.1	1.6	24.9	2.3	28.2	2.5

Conjointly, the results on the MAD-system showed an increase of D and SR with the V increase. For the mean population, the change in IdC with V followed those in D with V ($D=27.02V^{2.25}$, $IdC=44.70V^2-81.42V+19.02$, $0.81<r^2<0.99$) indicating that swimmers shifted from a great catch-up to a relative opposition mode of arm coordination to overcome the active drag, consecutive to the velocity increase. The adaptation of the motor organisation appeared adequate because it did not lead to greater IVV (CV remained close to 0.14). Indeed, through an incremental set of 200-m swims until exhaustion, Barbosa et al. (2006) confirmed that IVV is correlated with the energy cost in the four strokes, and particularly in freestyle (r=0.62). These results confirm the importance of increasing propulsive continuity by increasing IdC and minimising D that would warrant a great SL and V, because these modifications reduce IVV (Craig & Pendergast, 1979; Alves et al., 1996) as well as energy cost (Alves et al., 1996).

REFERENCES

1. Alves F, Gomes-Pereira J, Pereira F. (1996). Determinants of energy cost of front crawl and backstroke swimming and competitive performance In: Troup JP, Hollander AP, Strasse D, Trappe SW, Cappaert JM, Trappe TA (eds.). Swimming Science VII. London, E&FN Spon, 185-191

2. Barbosa T, Lima F, Portela A, Novais D, Machado L, Colaço P, Gonçalves P, Fernandes R, Keskinen K, Vilas-Boas JP. (2006). Relationships between energy cost, swimming velocity and speed fluctuation in competitive swimming strokes. Portuguese J Sport Sci, 6: 192-194

3. Chollet D, Chalies S, Chatard JC. (2000). A new Index of Coordination for the crawl: Description and usefulness. Int J Sports Med, 20: 54-59

4. Craig AB, Pendergast DR. (1979). Relationships of stroke rate, distance per stroke, and velocity in competitive swimming. Med Sci Sports Exerc, 11: 278-283

5. Potdevin F, Delignières D, Dekerle J, Alberty M, Sidney M, Pelayo P. (2003). Does stroke rate determine swimming velocity values and coordination? In: Chatard JC (ed.). Biomechanics and Medicine in Swimming IX. Saint Etienne, University of Saint Etienne, 163-167

6. Seifert L, Chollet D, Bardy B. (2004). Effect of swimming velocity on arm coordination in front crawl: a dynamical analysis. J Sports Sci, 22: 651-660

7. Seifert L, Chollet D, Rouard A. (2007). Swimming constraints and arm coordination. Hum Mov Sci 26: 68-86

8. Toussaint HM, Truijens M. (2005). Biomechanical aspects of peak performance in human swimming. Animal Biology *55*: 17-40

Stroke technique changes and expertise level during an all-out time trial in front crawl swimming

François Potdevin[1], Michel Sidney[2], Patrick Pelayo[2], Morgan Alberty[2]

[1]Education and Intervention Laboratory, University of Lille 2, Ronchin, France
[2]Human Movement Studies Laboratory, University of Lille 2, Ronchin, France

The aim of this study is to compare technical parameters changes in relation to technical skills during an all-out time trial. Eight national level swimmers (G_E) and ten occasional swimmers (G_{NE}) performed an all-out time trial of 2 minutes in front crawl stroke. Changes in Speed (ΔS, $m.s^{-1}$), Stroke Length (ΔSL, $m.cycle^{-1}$), Stroke Rate (ΔSR, hertz), Horizontality of the body (ΔH, degrees) and Breathing time (ΔB, s) were calculated between the first and last 30 seconds of the time trial and were compared between groups. Results showed significant greater value in ΔS, ΔSL, ΔH, and ΔB for G_{NE}, ΔS and ΔH being the largest. It is worth noting that the change in SR was not significantly different between groups. ΔH is significantly correlated to ΔS and ΔSL. Such results suggest that keeping the horizontality of the body during an exhaustive exercise is an ability that has priority to be learned in less expert swimmers to improve performance. Consideration of such parameters in the technical analysis could guide skill training process for young swimmers learners.

Key words: *skill level, evaluation, stroke technique*

INTRODUCTION

Comparison between experts and non experts is one mean to shed light on factors that might explain high performances and guide skill training process. To discriminate practice level, the deterministic Stroke Length (SL) * Stroke Rate (SR) model is the most used. Subsequent studies using this model highlighted that the higher velocities reached by experts are explained notably through greater values in the SL than less experts (1, 5). The higher the SL, the higher the swimming economy, since it reflects the ability of the swimmer to decrease drag (9), and a high propulsive efficiency (3). Moreover, experts are more able to reduce both decrease in the stroke rate and stroke length, during exhaustive exercises, leading to a greater stability in the swimming velocity (1, 5). Nevertheless, the time to perform a race distance, and thus the induced physiological stress, are widely different according to level of practice (4) and could bias the analysis of the stroking parameters changes between swimmers differing in skill. Indeed, the study of Chollet and Coworkers (1997) showed that between high and less skilled swimmers, the time to cover 100-m can double. To our knowledge, few studies have investigated the evolution of SL-SR combination between different expertise levels during identical time of exercise.

SR and SL are indicators of the underlying motor processes and the way the swimmer coordinate them to produce their characteristic stroke technique (8). Nevertheless, using solely this macroscopic evaluation is not sufficient to guide training process and prior technical ability to teach. Because of the relations between passive drag, stroke length, breathing actions and horizontality of the body (6, 7), it could be relevant to diagnose the evolution of these technical parameters according to expertise level. The more discriminated parameters could be accepted as the more prior aspect to develop in order to improve performance in non expert swimmers.

Thus, the aim of this study is to compare technical parameters changes in relation to technical skills during an all-out time trial. It is hypothesized that the less stable technical parameters correlated with reduction of velocity and or stroke length is the prior technical aspect to be learned in novice swimmers.

METHODS

Eight national level swimmers (G_E) and ten occasional swimmers (G_{NE}) with identical anthropometric characteristics performed an all-out time trial of 2 minutes in front crawl stroke. Mean values of age, height, body mass, arm span, and arms pan/height ratio were 22 ± 1 vs. 20 ± 2 years, 1.9 ± 0.03 vs. 1.88 ± 0.03 m, 81 ± 6 vs. 79 ± 7 kg, 1.94 ± 0.06 and 1.89 ± 0.05 m, and 1.02 ± 0.02 and 1 ± 0.02 for G_E and G_{NE} respectively. Neither anthropometrical characteristics did not differ significantly between both groups ($p>0.05$).

The tests were performed in front crawl in a 25 m indoor swimming pool. Subjects performed a 2 minutes time trial in which the longest distance is to cover.

The subjects were filmed in a sagittal plan using two cameras; one above the surface and one below the surface of the water. Videos analysis was made using DartTrainer software (Version 4.0.5 DartFish TeamPro) which allows the analysis of each stroke with an accuracy of 0.02 s.

Distance covered was measured in meters. The stroking parameters were measured and calculated continuously using a PC software developed in our laboratory. The Stroke Rate (SR in Hz) was measured cycle by cycle. The PC software allows the time per pool length to be measured. This time corresponded to split times between two consecutive contacts of the feet on the wall during each turn. In order to ignore the changes in speed at start and turns, the swimming speed (S, $m.s^{-1}$) was calculated from the 5th to the 25th meters of the swimming pool. Finally, the Stroke Length (SL, $m.cycle^{-1}$) was calculated as the ratio between S and SR.
According to the methodology of Kendjlie et al. (2004) an estimation of the horizontality (H, degrees) of the body was made twice during the stroke cycle, at each passage of the hands through the vertical plane of the shoulder. At this moment, the body roll value is near 0° and does not influence the measurements by changing the degree of rotation. The head-hip line angle with the water line was measured by digitizing the swim goggle as a marker of the head position, the lowest position of the spina iliaca as a marker for the hip position, and the lane rope behind the swimmer as the marker for the water line. Both estimated values are averaged to obtain a mean body angle inclination.
Absolute time for breathing action have been estimated by considering the time between the first lateral movement of the head and its last lateral movement to reach its initial position (B in s). Finally, B has been divided by the mean stroke cycle duration to obtain the time dedicated to breath per stroke cycle (B in % of the duration of the stroke cycle).
Variables were studied during the first (beginning) and the last (end) 30 s of the time trial. Variations of the variables between the beginning and the end of the time trial have been calculated according to the following formula:

$$\Delta = \frac{M_{end} - M_{start}}{M_{start}}$$

Where Δ is the variation of the variable, M_{End} and M_{Start} are the mean value of the variable at the end and the start of the time trial respectively.

Statistical analysis

Means and standard deviations (SD) were used to represent the average and the typical spread of values of the studied variables. The technical parameters and Δ have been compared between G_E and G_{NE} and the start and the end of the trial thanks to a two way ANOVA. Correlations have been tested in order to detect if any variations of one technical parameters is related to each others.When normality and homogeneity of variance were met, Bravais-Pearson coefficient of correlation has been used. Otherwise, the Spearman coefficient of correlation has been used. The level of significance was set at the 0.05 level of confidence. This statistical analysis was realized with the use of the STATISTICA 6.0 software for PC.

RESULTS

Distance covered by G_E and G_{NE} was 181.2±6.9 m and 116.3±8.6 m respectively. Technical parameters measured during the first (beginning) and the last (end) 30 s of the time trial are presented in table 1. V, SL and corresponded Δ are significantly higher for G_E. B is significantly higher for G_{NE} at the end of the trial. H and corresponded Δ is significantly lower for G_E. Significant correlations between ΔV and ΔH (r=-0.61), ΔV and ΔSL (r=0.7), ΔSL and ΔB (r=-0.67), and ΔSL and ΔH (r=-0.62) have been observed for G_{NE}. Significant correlations have been observed for G_E between ΔV and ΔSR (r=-0.74), and ΔSL and ΔB (r=-0.68). A significant interaction have been found between factor group and time for SL and H ($p<0.05$).

Table 1 : Mean values (±SD) of the velocity (V), stroke length (SL), stroke rate (SR), horizontality (H) and breathing time in relation to time (B) at the start (first 30s) and the end (last 30s) of the trial for the expert (G_E) and non expert (G_{NE}) groups.

	G_E			G_{NE}		
	Start	End	Δ	Start	End	Δ
V ($m.s^{-1}$)	1.45±0.07	1.12±0.09°	-21.33±7.31	1.09±0.1*	0.71±0.1*°	-34.09±8.54*
SL ($m.cycle^{-1}$)	2.16±0.15	1.92±0.22°	-11.49±7.44	1,64±0,29*	1.25±0.23*°	-23.07±11.08*
SR (Hertz)	0.72±0.07	0.64±0.05	-9.97±10.31	0.69±0.1	0.59±0.05°	-14.14±11.36
H (degrees)	8.68±2.07	9.87±1.59	18.2±27.89	9.92±4.62	17.44±9.61*°	76.24±16.31*
B (%)	68.38±4.04	62.72±5.35	14.68±17.80	76.47±11.01	96.65±62.52*°	47.47±61.38

*, significant difference between G_E and G_{NE} ($p<0.05$)

°, significant different from the beginning of the time trial ($p<0.05$)

DISCUSSION

The aim of the present study was to compare technical parameters changes in relation to technical skills during an all-out time trial. Our results showed that using this kind of test to compare different level of expertise yield different results from the scientific literature. Indeed, according to Chollet et al. (1997), the higher the technical skills, the higher the SR values adopted during the race. Our results showed no significant differences according to the groups, thus the physiological stress appeared to be similar between the two groups.

Concerning the changes in the stroking parameters, as for the study of Chollet et al. (1997), it have been observed a greater decrease in V, and SL for the less expert swimmers. These results demonstrated again that SL is the main parameter which is responsible for the decrease in V for G_{NE}. An interesting result is the statistical interaction found between the time and the group for SL. It means that the less expert the swimmer, the greater the decrease in SL. The SR decreased for both group but these decreases are not significantly different from one group to another. H and B significantly varied throught time for G_{NE} whereas slight but no significant variation was observed for $G_{E.}$ With the other interaction found for H alongside a significant correlation between ΔSL, and ΔH, our results strongly suggest the role of the increase in obliquity in the decrease of SL. In fact, a lesser body horizontality could increase the body surface area which could imply an increase in the body drag. In a learning perspective, the present result means that the maintenance of the body horizontality is priority skill that has to be learned to be able to keep the highest swimming speed. Althought no link have been observed between ΔB and ΔH, increase in H could be related to insufficient adaptation to the breathing constraint induced by aquatic displacement, as breathing take more time whithin a stroke cycle duration for G_{NE} at the end of the time trial. It means that breathing take place during propelling time, which could lead to inefficient propulsion. For expert swimmers, consideration of breathing pattern and body horizontality seem insufficient to explain the changes observed in stroking parameters. Consideration of other kinematical parameters, such as arm stroke phases and arm coordination, could help us to infere about intra-cycle changes that could occur to explain decrease in V and SL. Moreover, the variation of speed of expert swimmers is in a nearly same extend, related to the decrease in SR.

To conclude, according the skill level of the observed group, relationship between stroking parameters and intracycle parameters seems to differ and coul explain differences in performance. It showed the importance of technical evaluation to guide training intervention for skill acquisistion. For less expert swimmers, the maintenance of the body horizontality throught time, thank to an improvement of breathing pattern, seems to be a prior skill to learn to improve performance. For expert swimmers, trainers should work on both technical and physiological determinants of performance. Further studies, that consider other technical parameters, are needed to better explain changes in the stroking parameters.

BIBLIOGRAPHY

1. Chollet D, Pelayo P, Delaplace C, Tourny C, Sidney M. (1997). Stroking characteristic variations in the 100-m freestyle for male swimmers of differing skill**.** Percept Mot Skills, 85(1): 167-177.
2. Chollet D, Chalies S, Chatard JC. (2000). A new index of coordination for the crawl : description and usefullness. Int J Sports Med, 21(1): 54-59.
3. Costill DL, Kovaleski J, Porter D, Kirwan J, Fielding R, King DL. (1985). Energy expenditure during front crawl swimming: Predicting success in middle-distance events. Int. J. Sports Med, 6: 266-270.
4. Craig AB, Pendergast DR. (1979). Relationships of stroke rate, distance per stroke and velocity in competitive swimming. Med Sci Sports Exer, 11(3): 278-283.
5. Craig A. B., Skehan P. L., Pawelczyk J. A., Boomer W. L. (1985). Velocity, stroke rate, and distance per stroke during elite swimming competition. Med Sci Sports Exerc, 17(6): 625-634.
6. Kjendlie P-L, Stallman RK, Stray-Gundersen J. (2004). Passive and active floating torque during swimming. Eur. J. Appl. Physiol, 93 : 75-81.
7. Lerda R., Cardelli C. (2003) Breathing and propelling in crawl as a function of skill and swim velocity. Int J Sports Med, 24 : 75-80.
8. Pelayo P, Alberty M, Sidney M, Potdevin F, Dekerle J. (2007). Aerobic potential, stroke parameters, and coordination in swimming front-crawl performance. Int J Sports Physiol Perf, 2: 345-357.
9. Sanders R. New analysis procedures for giving Feedback to Swimming Coaching and Swimmers. (2002) In: Gianikellis KE, Mason BR, Toussaint HM, Arellano R and Sanders RH (eds.) Scientific Proceedings - Applied Program XXth International Symposium on Biomechanics in Sports – Swimming, 1-14.

Effect of velocity and added resistance on kinematical and kinetical parameters in front crawl

Schnitzler C.[1,2], Brazier T.[3], Button C.[3], Chollet D.[2]

[1] Human performance dept, Faculty of Sport Sciences, Marc Bloch University, France

[2] CETAPS EA 3832, Faculty of Sports Sciences, University of Rouen, France

[3] Human Performance Centre, School of Phys. Ed., University of Otago, New Zealand

Abstract

The effect of increasing velocity and adding resistance on kinematical and kinetical parameters during the stroke cycle was examined in front crawl for 7 national level swimmers. In a flume, 3 drag conditions provided by a resistance parachute (PA) were tested at 5 velocities. Video footage and force sensors were used to measure the spatio-temporal coordination and force parameters. The results showed that an increase in velocity (V) led to increases in stroke rate (SR), Index of coordination (IdC), and a non significant change in force impulse per cycle, whatever the condition. In PA conditions, significant increases in the IdC, force impulse, and a decrease in SR were recorded ($p<0.05$). These results show that in normal conditions swimmers adapt to a change in velocity by modifying kinematics rather than kinetical parameters, whereas in PA conditions there is an enhancement of both of the parameters.

Introduction

Literature has shown that swimming performance depends upon different kinematical parameters, such as spatio-temporal (stroke rate, stroke length) [2], temporal organization of the stroke (Index of Coordination, or IdC) [3] and kinetical (rate of force application) parameters [5]. These parameters are key identifiers in analysing changes occurring within the front crawl stroke with evolving conditions. In the first case, the adaptations of kinematical parameters to an increase in velocity have been widely studied. Several authors [3, 6, 7] show an increase of stroke rate (SR), index of coordination (IdC) and propulsive phase duration (Ppr). However, very few studies have dealt with the adaptation of kinetical parameters across different swim paces. This issue is of importance, since the ability to develop high rate of force application has been correlated with performance level [8]. To work on this issue, coaches often try to use alternative means to develop strength as a training increment to enhance performance.

Methods using additional devices to increase the amount of drag faced by the swimmer have been suggested [1]. Recently, a method based on a specific parachute has been proposed to develop specific strength in the water. However, the effect of such device on stroke mechanics and the development of force by the swimmer is unknown. The aim of this study is to then examine kinematical and kinetical evolution of the front crawl stroke in different conditions of pace and additional drag. The hypothesis being tested are (1) that swimmer adapt to different paces by modifying mostly kinematical parameters and (2) that additional resistance allows the subjects to increase both the duration of the propulsive phase and the magnitude of force impulse per stroke.

Methods

Seven well trained male swimmers of 17.14 ± 2.73 years, swimming 57.67 ± 1.62s for 100m of front crawl participated in the present study, which was approved by the University of Otago ethics committee. The protocol took place in a swimming flume where water flow velocity could be controlled by the experimenter. Different drag conditions were provided by a resistance parachute which hangs from the waist 60cm below the feet. The protocol used to add drag consisted of varying the parachute diameter to create for 3 different conditions (1) free swimming, (2) open parachute (small additional resistance), (3) half closed parachute (high additional resistance). The subjects then had to swim at five different velocities from 60 – 100% of maximum speed in the three different conditions. To determine the velocity in which the parachute conditions were to be swum at a drag-velocity relationship was developed through 10 passive drag trials per condition. A second-order equation was set between velocity and drag for each condition, and use for the correspondence between paces across condition.
Video analysis: Four 50 Hz video cameras were genlocked around the flume from two front angles (left and right) to record kinematical data. Stroke rate and stroke length, as well as coordination parameters (IdC and stroke phases: catch (A), pull (B), push (C), recovery (D), Ppr = B+C) were determined according to Chollet et al. [3] methods.
Determination of force parameters: On the right hand 4 pairs of pressure sensors are glued to the surface of a glove on both the palmer and dorsal sides of metacarphalangeals II, III, IV, and V. The sensors were connected via a series of wires to a 12 entry amplifier, connected itself to a computer to record the force data, and

calibrated in the water. Mean pressure was obtained using the following equation: $P_{mean} = 0.045P_A + 0.186\ P_B + 0.554\ P_C + 0.013\ P_D + 7.558$, and the obtain value is then multiplied by the hand plane area (m^2) to calculate the resultant propulsive force, according to Takagi and Wilson method [9]. Three cycles were recorded per swim trial. A matlab routine was created to integrate the force-time data to calculate force impulse, and note down the magnitude of the two main peaks per stroke. Video footage was then used to note down the magnitude of both the pull and push phases main peak during each stroke. The data was then divided by 3 (the number of cycles taken into account) to get an average force impulse, pull and push force peak per stroke.

Statistical Analysis: This study involves five dependent variables: SR, SL, IdC, stroke phase, force impulse, pull and push peak propulsive force, and two dependant variables: velocity and resistance condition (Free swimming, Fully open, and Half closed). After verification of the initial condition of normality (a Ryan joiner test) and homogeneity of variance (Bartlett test) multiple two-way anovas (analysis of variance) are used to analyse the difference in the conditions (swim paces×parachute condition). A Tukey's post hoc test helped to locate these differences.

Results

The evolution of spatio-temporal, coordination parameters is summarized in the Table 1 for different pace and parachute condition, and in Table 2 for force parameters.

Table 1: Evolution of kinematical parameters as a function of pace and parachute conditions.

pace condition	V (m/s)	SR (str/min)	SL (m)	IdC (%)	A (%)	B (%)	C (%)	D (%)	Ppr (%)
V1 (60%)	0.97±0.22	34.77±3.10	1.68±0.34	-3.49±6.11	32.69±6.91	22.73±4.18	23.85±4.06	20.73±2.17	46.58±6.09
V2 (70%)	1.11±0.21	37.71±2.69	1.76±0.34	-3.29±6.20	31.79±7.14	22.68±3.44	23.84±3.41	21.68±2.33	46.53±6.13
V3 (80%)	1.23±0.23	42.42±2.92	1.74±0.28	-1.39±5.65	29.64±6.57	24.33±3.22	24.24±3.32	21.78±2.26	48.58±5.57
V4 (90%)	1.37±0.27	46.94±3.43	1.75±0.28	0.11±5.24	27.86±5.63	25.53±3.26	24.75±2.92	21.86±2.06	50.28±5.29
V5 (max)	1.47±0.28	51.81±5.49	1.70±0.26	2.43±5.79	24.87±6.43	27.05±4.45	25.39±2.48	22.68±2.24	52.44±5.68
Difference	*	*	NS	*	*	*	NS	NS	*
parachute condition	**V**	**SR**	**SL**	**IdC**	**A**	**B**	**C**	**D**	**Ppr**
Free	1,50±0,27	44,29±8,19	2,05±0,26	-2,99±5,68	30,31±7,24	23,26±3,10	23,66±3,88	22,77±2,26	46,92±5,69
Open	1,17±0,20	42,41±6,01	1,65±0,14	-1,34±5,62	29,60±6,53	24,07±4,38	24,69±2,72	21,64±2,01	48,76±5,61
Half closed	1,01±0,15	41,18±6,75	1,48±0,08	0,83±6,50	28,36±7,25	25,97±4,08	24,87±3,05	20,80±2,09	50,84±6,39
Difference	•	•	•	•	NS	•	NS	•	•

* : significant pace effect •: significant parachute condition effect NS: non significant difference.

Pace effect: V, SR, IdC, B, Ppr increased significantly with pace, whereas A decreased significantly ($p<0.05$).

Parachute condition: V, SR, SL, D decreased significantly, whereas IdC, B and Ppr increased significantly ($p<0.05$). Tukey post-hoc test shows that the latter parameters differ only between free swimming and half-closed parachute condition.

No significant pace × parachute condition effect was recorded for any kinematical parameter.

Table 2: Evolution of force parameters as a function of pace and parachute conditions.

Pace effect	Force impulse (N.S)	Pull peak force (N)	Push peak force (N)
V1 (60%)	39,40±9,59	55,42±13,38	77,69±17,82
V2 (70%)	38,08±6,54	54,48±7,82	77,91±13,06
V3 (80%)	37,31±6,99	60,30±10,85	78,78±12,53
V4 (90%)	36,47±8,38	64,38±13,91	79,22±16,07
V5 (max)	37,54±8,47	68,71±13,62	82,49±18,60
Pace	NS	*	*
Parachute condition	**Force impulse (N.S)**	**Pull peak force (N)**	**Push peak force (N)**
Free	36,37±8,91	62,11±14,27	77,25±17,80
Open	35,96±6,45	56,44±10,62	75,24±10,25
Half closed	41,03±7,07	62,07±12,86	84,78±15,03
Condition	•	NS	•

* : significant pace effect •: significant parachute condition effect NS: non significant difference.

Pace effect: pull and push phase peak force increased significantly ($p<0.05$), whereas no significant change is recorded for force impulse.

Parachute condition: force impulse and push phase peak force increased significantly ($p<0.05$), whereas no significant change is recorded for pull phase peak force. Tukey post-hoc test shows that the latter parameters differ only between free swimming and the half-closed parachute condition.

No significant pace × parachute condition was recorded for any kinematical parameters.

Discussion:

The objective of the study was to examine the effect of velocity and the use of a specifically designed parachute on spatio-temporal, coordination and force parameters for subjects facing equivalent drag across various conditions.

The changes for spatio-temporal and coordination parameters for pace effect, outlined in the Table 1, follow the results generally established in the literature: when swim pace goes from low to high speed, there is a significant increase of SR and IdC, with the latter result being explained by a decrease in catch phase (A) and an increase in pull phase (B) duration [3, 6, 7]. The Table 2 shows that the force impulse developed per stroke, which is equal to the force applied times the length of the time interval over which it is applied, does not vary significantly across paces, even if there is a significant increase of both pull and push phase peak force ($p<0.05$). This previously unreleased result indicates that kinematical parameters (SR, IdC, Ppr) are of more importance than kinetical ones (force impulse) to adapt to the change in swim pace in experienced swimmers.

Some changes are outlined on both kinematical and kinetical parameters with the different resistance device condition. Here, table 1 indicates that the use of the parachute implies a significant decrease of V, SR, SL and catch phase (A), whereas IdC and push phase (C) improve significantly. Tuckey post-hoc test shows this difference to be significant between free swimming and half-closed parachute condition, which is the higher additional drag condition. The modification of V and SL is just a mechanical consequence of the protocol, as keeping drag constant in different conditions implies a reduced speed of the flow, and therefore SL. But interestingly these results imply that the use of this device modifies the organisation of the stroke by compelling the swimmer to lower his stroke rate and enhance his propulsive phase duration by decreasing the catch phase (A) and increasing the push phase (C) duration. In free the swimming condition these results are typical for swimmers whom are trying to increase their velocity [3, 6, 7]. However, two elements indicate that the parachute device changes the swimming pattern more than expected. Firstly, the fact that at each pace, the total resistance faced by the swimmer is the same whatever the condition, as testified by the drag-velocity relationship for each condition. Secondly, those kinematical changes are accompanied by kinetical changes that do not occur in the free swimming condition, as shown by a significant increase in the force impulse (as well as push peak force). This signifies that both the mean and peak force improves with additional resistance from the parachute. This result is of importance, as it shows that through training with the parachute swimmers could enhance the power that they apply per stroke, which is a crucial element in improving ones swimming performance [1, 4]. The tukey post-hoc test shows that those changes are significant only with a half-closed parachute as compared to free swimming condition ($p<0.05$), with an improvement of 11.3% for force impulse and 8.9% for push phase peak force respectively. This result therefore indicating that a change in the stroke mechanics necessitates the swimming condition to be very different from normal swimming.

It is important to notice the lack of significance of the pace × condition interaction, which indicates that those changes with pace and condition are occurring whatever the parachute condition. In that sense, the use of the parachute device does not change the global adaptation of swimmer with pace.

Conclusion

By providing for the first time an indication about the evolution of spatio-temporal coordination and force parameters across pace and additional loads, this study has highlighted two new characteristics of well-trained swimmers.

Firstly, the way of adapting to different velocities (or paces) is made rather on a kinematical (spatio-temporal and coordination) than on a kinetical (force impulse) basis, even if an increase in peak force during both the pull and push phase are recorded.

Secondly, that the use of additional resistance provided by a parachute implies a reorganisation of the swimming pattern that would not have occurred in a normal swimming condition. In that sense, the use of parachute training seems to be an interesting way to to enhance propulsion in both the duration of the phase and mean and peak force developed during the front crawl stroke.

References

1. Arellano R, Pardillo S. (1992). An evaluation of changes in the crawl-stroke technique during training periods in a swimming season. Biomechanics and Medicine in Swimming 6: 143-149

2. Chatard JC, Collomp C, Maglischo E, Maglischo C. (1990). Swimming skill and stroking characteristics of front crawl swimmers. Int J Sports Med 11: 156-161

3. Chollet D, Chalies S, Chatard JC. (2000). A new index of coordination for the crawl: description and usefulness. Int J Sports Med 21: 54-59

4. Hopper R, Hadley C, Piva M, Bambauer B. (1983). Measurement of power delivered to an external weight. in AP. Hollander, PA. Huijing, G. de Groot (Eds) Biomechanics and Medicine in Swimming Champaign, Illinois: Human Kinetics Publishers 4: 113-119

5. Schleihauf RE, Gray L, DeRose J. (1983). Three-dimensional analysis of hand propulsion in the sprint front crawl stroke. In: Hollander AP, Huijing PA, De Groot G (eds). Biomechanics and medicine in swimming science IV. 173-183

6. Schnitzler C, Seifert L, Ernwein V, Chollet D. (2007). Arm Coordination Adaptations Assessment in Swimming. Int J Sports Med

7. Seifert L, Boulesteix L, Carter M, Chollet D. (2005). The spatial-temporal and coordinative structures in elite male 100-m front crawl swimmers. Int J Sports Med 26: 286-293

8. Sharp RL, Troup JP, Costill DL. (1982). Relationship between power and sprint freestyle swimming. Med Sci Sports Exerc 14: 53-56

9. Takagi H, Wilson B. (1999). Calculating hydrodynamic force by using pressure difference in swimming. In: Keskinen K, Komi P, Hollander AP (eds). Biomechanics and Medicine in Swimming VIII. Jyvaskyla: Gummerus Printing 101-106

Stroke rate and stroke distance in swimming, reconsidered

Bodo E Ungerechts[1], Anna C Schmidt[2]

[1] University Bielefeld, Department of Neurocognition and Action-Biomechanics, Germany

[2] University Göttingen, Department of Society and Training, Germany

Swimming is a typical cyclic activity powered by muscular energy supply. Per cycle the speed of the body is determined by the displacement of the body and the duration of each cycle. New research considering cognitive aspects of stroking reveals that highly skilled swimmers are concentrating on each stroke (even in competition). The displacement a body travels while stroking can be determined by two different approaches: a) direct measurement and b) indirectly by calculating the stroke distance. The purpose of this paper is to compare the displacement of the body-path of 22 age-group swimmers measured directly length during one arm cycle with calculated stroke distance. The comparison is based on the assumption that 3 quarter of a full cycle is "involved"; hense the ratio of body-path (p) to stroke distance (d) is : (p) = 75 % (d). The results reveal that the ratio body-path (p) to stroke distance per stroke (d) is (p) = 77 % of (d). The correlation of (p) over (d) is reasonable (r = .78). Hense, the calculated stroke distance is a representative figure of the effect of both arm actions.

Keywords: *crawl stroke, stroking parameter, stroke distance, age-group*

INTRODUCTION

Swimming is a typical cyclic activity since the motion of limbs is recurring in cycles powered by muscular energy. In aquatic space, during each limb cycle, water mass is set in motion creating momentum and in reaction a momentum is transferred back to the body changing the motion of the body. The mean speed (u) is depending on a) the stroke distance (d) that a swimmer is moved horizontally and b) the duration (T, measured in seconds) per stroke cycle. Mean speed u can be calculated as follows:

$u = d/T$ [m/s]

The measurement of the duration of one cycle (T) can easily be done. By using a special clock the stroke rate (N, number of cycles per minute) can be clocked (Fig. 1).

Fig. 1 A race stop watch specialised to measure simultaneously time and the stroke rate per minute (N) – here N = 32 / min.

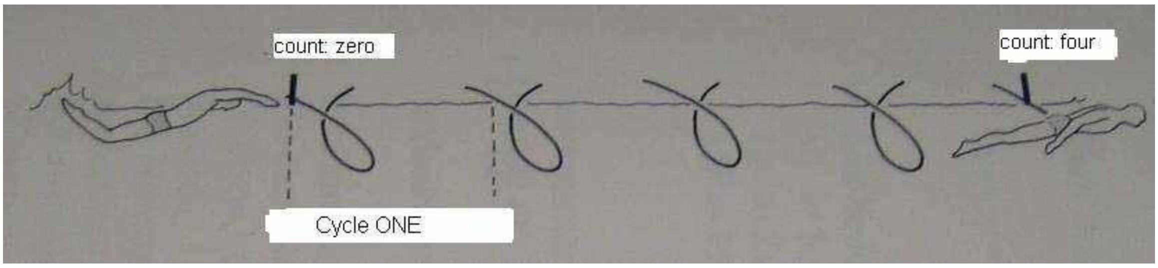


Fig. 2 Four cycles of a butterfly swimmer in the correct water related view.

Usually strokes are determined per minute measuring the period for four consecutive strokes – counting: zero, one, two, three ! (Fig. 2).

The duration of one cycle (T) is more practical for biomechanical purpose instead of strokes per minute; the conversion from stroke rate per minute (N) to duration of one cycle (T) is as follows:

$T = 60/N$ [s] • $N = 60 / T$ [cycles / min] • $N * T = 60$ [s]

The stroke distance (d, measured in meters) mostly cannot be measured directly. The stroke distance (d) is calculated indirectly using mean speed u and duration per stroke T as basic factors; it follows

$d = u * T$ [m]

When (d) is calculated this way it is questionable to relate it statistically to (T) as often published, because in this case the factors are not independent. Provided (d) is measured directly during experiments a calculation of statistical relationships is feasible.

In swimming competitions and daily swim training the factors mean speed (u) and stroke rate (N) are registered more or less regularly. A colleague from Estonia is presenting the complete data-set –u, N, d-per participant of all finals during international competitions. The results of competition analysis leave some questions open concerning aspects, like:

• Are there best-values of duration T / stroke distance d per swimming technique?

• Are duration and stroke distance independent?

• Do duration and stroke distance per stroke change during a race in a regular manner?

• Are duration and distance related to age / experience of the swimmer?

• Can duration and stroke distance be trained separately?

The purpose of the paper is to present some global thoughts considering the relationship of the factors before presenting selected findings.

Race analysis: Very, very often coaches and swimmers are disturbed by the fact that different swimmers achieve the same mean speed (u) with different stroke rates by, e.g. u = 1.82 m/s in 100 m freestyle Woman N1 = 47 and N2 = 53, respectively; consequently, stroke distance is different: d1 = 2.21 m and d2 = 1.97 m.

In 2003 a new WR on 200 m freestyle Woman has been set in 1:56,64 min. Per 50 m the lap times were as follows: 27.14 / 29.13 / 30.06 / 30.31, the stroke rates: 47 / 42 / 39 / 40 per minute and stroke distances: 2.23 / 2.40 / 2.46 / 2.37 m. The average stroke rate for this swimmer was SR = 42 / min and average stroke distance d = 2.36 m in comparison to 46 / min and 2.10 m for other female swimmer. For further reasoning one would like to know if Swimmer 1 is stronger / taller / more skilled than Swimmer 2. Probably Swimmer 2 was told that higher stroke rate is a prerequisite to swim faster.

Another observation due to competition analysis reveals that the stroke rate at the beginning of a competition is higher than in the last lane. Ungerechts & Thiesmann (1995) showed that the stroke duration (T) at the end of a race is longer compared to the first lane: 3.9 % ($r^2 = 0.85$) in male and 6.5 % ($r^2 = 0.93$) in female events, relevant for all four strokes.

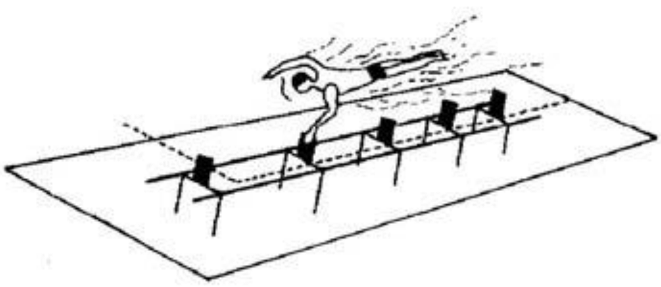
Stroking parameters and energy-rate: In competition swimmers swim at highest possible power delivery. Taking into account the low efficiency of activities in aquatic space – only 7 – 9 % of the total power is converted to speed -one question is about the advantage achieving a certain swimming speed at lower stroke rate (longer duration T of each stroke cycle). The answer should be related to aspects how muscles are transforming energy per time and how highest muscular tension is produced. In any case power is needed to make cyclic neuro-muscular actions happening and to move the masses of water and the body, respectively.

Biological cells like muscle cells can transform energy at different speed which determines the power delivery. Energy-rate depends on the “fuel” which can be transformed and how the body deals with the intermediate energy products (there is no waste of energy). The energy-rate is higher at the beginning of an event than on the last lane – provided high power is wanted and the total load period is below 2 min.

High performance sports need some muscle tension to move the body. From muscular-physiological point of view a relatively slower action is connected to higher production of tension (Hill, 1950). According to this principle, swimming at relatively fewer stroke rates is advantageous, since relatively higher muscle tension can be produced.

Higher stroke rate (N) are "more expensive", since the trained energy stocks are faster depleted. Fewer stroke rate or longer duration of one stroking cycle (T) enables longer stroke distance (d) and much better concentration on the details of the stroke action. The longer stroke distance d can be attributed either to higher muscular tension and/or to finer action control. In any case the lower (possible) stroke rate is more efficient, since it is more productive with less effort.

Stroking parameters and anthropometrical aspects: Assumed water provides bearings (fixed pads) where the swimmer can anchor the hand(s) and move the body relatively to this hand forward like it is possible on MAD-S (Fig 4), a device constructed by Toussaint et al. (1988). A meaningful distance between the pads could be related to arm-length (AL), since a hand reaching out had to leave a pad when the body is moved 2 AL (for some reason the distance between the pads are mostly set to 1.35 m).



Fig, 3 Measuring Active Drag System (MAD-S).

In a study using MAD-S the following questions were: a) to which extend the body shape is decisive for the speed a swimmer could swim under this conditions and b) to which extend the muscular strength is? Male swimmers were paired according to 1) anatomical data and 2) muscular strength supposing they will swim similar speed because of similar drag. However, it turned to be that something else was decisive for the speed the individuals achieved. The swimmer "swam" faster who was able cover the fixed distance between two pads in shorter duration T. This means these swimmers could work on higher energy-rate, delivering more power at higher speed.

In aquatic space situation there are no pads to anchor the hand. Anyhow, the stroke distance (d) can be related to the arm length (measured from sternum to finger tips). Relating the (calculated) stroke distance (d) of a group of swimmers when swimming crawl stroke at fastest speed to their individual arm length (AL) the result was: d = 0.68 * 4 AL (male) and d = 0.62 * 4 AL (female). It is hypothesized that arm length is a determinant individual factor, explaining why long swimmers do have some advantage in freestyle, backstroke and butterfly (provided skillness is likewise developed).

Stroking parameters in workouts: In training situation the speed is mostly much slower than in competition. Under these circumstances the swimmer may "play" with the stroke rate. It is known that the three factors are closely related. This includes that increasing mean speed (u) at short (d) is demanding shorter periods of cycles (T): u = 2.0 m/s are possible either by a combination of d = 3 m and T = 1.5 s or d = 2 m and T = 1.0 s or d = 1.5 m and T = 0.75 s. If the stroke rate N is increased voluntarily, the stroke distance (d) drops and consequently the swimming speed. The actions become less efficient. The results of a stroke-step-test (Breaststroke), 25 m, each with increasing stroke rate, are represented in Fig 4 a.

Fig 4 a: Speed–stroke-rate–distance-per-cycle 4, b: Power-Stroke rate curve.

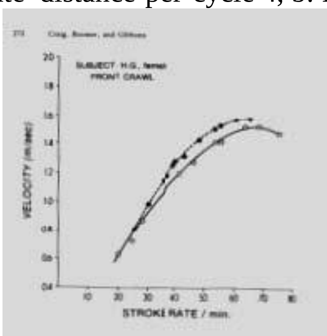


Fig. 5 Inverted U-shaped curve of the cycles per minutes during step test swimming, implying an optimum during per cycle for each swimmer.

Ungerechts (1979) studied the individual development of factors d, T and u applying the concept of Craigh et al (1979). Individual swimmers had to swim several times 25 m, like a step test from slow to personal fastest speed while 10 m were taken as measuring section. The individual data were transferred to a graph “speed over stroke rate”. In this graph the stroke distance is also introduced via isographs (Fig. 4a). Inspection of the graph “speed over stroke rate” reveals a similar shape like the “power over stroke-rate” curve (Fig. 4b), including the optimal trend. The power output is coupled to the number of muscular cycles or stroke rate and follows an optimal trend (Fig 4b). This means, power output is increasing until a certain number of cyclic actions or stroke rate is reached. It is advised to execute this stroke-rate step-test with all (at least talented) swimmers, repeatedly to show swimmer’s development.

Provided the swimmer increases the propelling efficiency -more stroke distance (d) at same stroke rate (duration of the stroke), the individual curve is shifted to the left (Fig. 5).

Another practical aspect of these tests is that coaches know exactly the individual efficient stroke rate. This then can be reversed in training. Since in daily workouts the speed is much lower than in races the coach easily can check if stroke rate and mean speed fits for individual swimmers, sometime called “appropriate relationship”.

Unsteadiness of stroking parameters

Own studies, comparing the d, T and u relationship in races and training revealed something unexpected. These swimmers selected much higher stroke rates during competition than in the test situation. In both case they achieved same speed.

Table. 1 d, T and u relationship of an elite breaststroker.

	u[m/s]	N[1/min]	d[m]
Competition	1.40	52.0	1.62
	1.30	46.0	1.69
Testsituation	1.40	45.0	1.73
	1.30	36.5	2.16

Table. 2 d, T and u relationship of an elite butterfly swimmer.

	u[m/s]	N[1/min]	d[m]
Competition	1.70	68.0	1.50
	1.50	56.6	1.57
Test-situation	1.70	58.8	1.73
	1.50	46.0	1.95

It is much likely that both swimmers were convinced those much higher stroke rates are essential to achieve higher speed. After they understood that higher stroke rate may result in lower efficiency they changed their concept of stroking and reached more stable results in competition. They also understood that higher stroke rate is reducing the momentum production. It is recommended to swim also in competition at lower (possible) stroke rate. The appropriate individual stroke rate can be studied by using the test mentioned before.

METHOD

It is a principal question in which way the calculated stroke distance (d) a swimmer travels per cycle is matching with the measured displacement of the body, called body-path (p) per hand action. There is of course one problem when dealing with crawl or back stroke since for a certain period of time both hands are acting below waterline (Fig 6). The calculation however is based on one cycle which is in crawl or back stroke the time of both arms acting (Fig. 7). Measuring the body-path (p) in freestyle can be done by using Dartfish software measuring the horizontal displacement of the vertex of the head in the period when one "reference" hand enters and leaves water. In this study 22 junior swimmers were asked to swim freestyle fast at 25 m – just using arms while the legs were supported by pull-buoys.

Fig. 6 Both hands are acting below waterline.

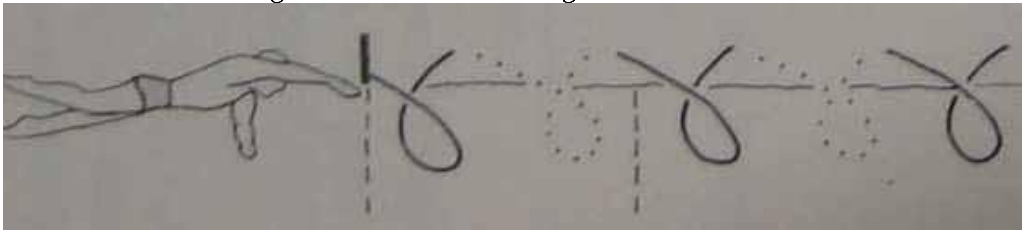


Fig. 7 An arm-cycle in freestyle is the period of the action of both arms (dotted + full lines).

The swimmers were just preparing for their first National Junior Championships.

During that arm sprint the time between 10 to 20 m and the stroke rate were registered, simultaneously. In addition the swimmer was filmed with a digital video camera (Sony DCR-HC94E) fixed underwater.

During that arm sprint the time over 10 m distance –between 10 to 20 m -and the stroke rate were taken, simultaneously. In addition the stroking swimmer was filmed with a digital video camera (Sony DCR-HC94E) fixed underwater. The displacement of vertex was measured by Dartfish-software during the period when one hand enters and exits water, called body-path (p).

RESULTS

The period of one arm action below waterline is not equivalent to the duration of "one cycle". While one hand enters water the opposite hand is still interacting with some water mass and the mutual effect on body-path has to be considered. The results were as follows

- 10 m were covered in t(10) = 7.48 s (± .58 s)
- clean speed was u = 1.35 m/s (± .11 m/s)
- measured body-path was p = 1.37 m (± .18) m
- calculated stroke distance was d = 1.77 m (± .24) m
- ratio of body-path to stroke distance (p / d) = 77.73 %.

The swimmers used different times to cover 10 m and using different length to displace the body. In Fig. 8 the results of stroke distance and body-path are represented over the time for 10 m. The trend-lines are different: the body-path-line stayed nearly horizontal –at all speeds whereas the stroke-distance-line increased with shorter periods (increasing speed). The direct relation between the displacement and stroke distance is shown in Fig 9. The correlation coefficient is r = 0.78 which is reasonable.

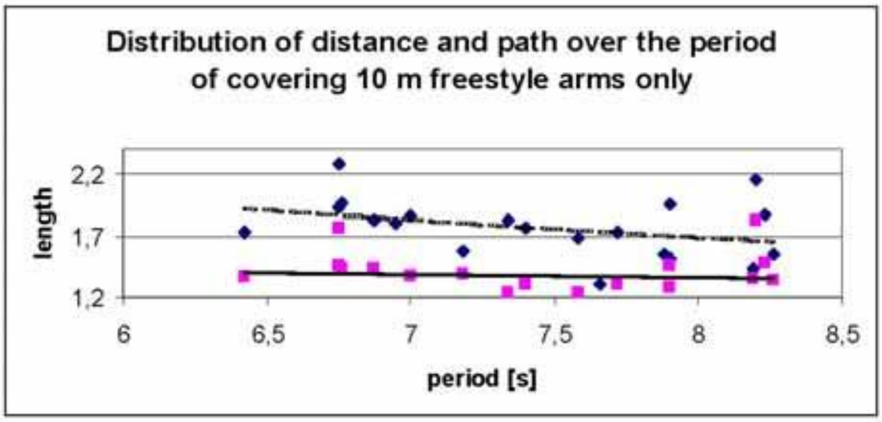


Fig. 8 Comparison of the distribution of body-path (p) during the period of underwater action of one arm (squared symbols) and stroke distance (rhombus shape) over time for 10 m.

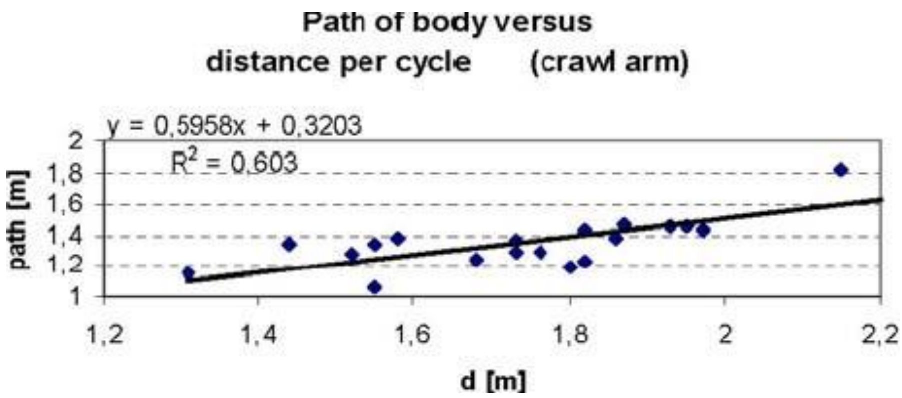


Fig. 9 Statistical comparison of body-path (p) during the period of underwater action of one arm and calculated stroke distance (d), based on 25 m crawl sprint, arms only

DISCUSSION

The ratio of measured dispacement of body (body-path) during the period of the underwater action of one arm versus calculated stroke distance was 77,73 %. This figure is closely to the theoretical number of 75 %. The calculated stroke distance (d) is based on the contribution of both arms thus to say the full cycle consits of 4 quarters or arm length. Principally, during the period of the underwater action of one arm, this arm contributes two quarters and the opposite one quarter. Hence, the calculated stroke distance (d) is a reliable measure.

There are two trends when comparing of the distribution of body-path (p) during the period of underwater action of one arm and calculated stroke distance (d) in relation to the the time needed to cover 10 m during a 25 m crawl sprint, arms only. The stroke distance (d) was nearly constant. Hence, the time per 10 m the swimmers achieved is related to the distance covered.

When looking at the body-path (p) the trend is decreasing, the slower swimmer did not reach the 75 % contribution.

The particular importance of stroke distance (d) for effective stroking was shown by Wirtz et al (1997) when studying the effect of supramaximal crawl sprint on duration of one stroke and stroke distance. The assisted speed levels were: 1,8 -1,95 – 2,08 -2,15 m/s. The results revealed “the distance (d) per cycle continuously increased” indicating the relevance of (d). There was no change of duration (T) of the cycle. In addition, it was reported that the trajectories of the wrist below water (sagital plane relative to water and) is showing principally similar shape (multiple comparison of means by

Student-Newman-Keuls-Test), with a slight trend that during assisted swimming the curve is slightly tilted and “compressed” as if “the arm is being pushed backwards” due to higher flow speed. Consequences for mental adaptation were not tackled.

Keskinen (1997) pointed out that stroke distance (d) is “one of the best indicators of effective swimming”. Studying the cause and effect of fatigue in swimming it was concluded that a decline of speed during races is “almost completely” accounted for by increasing stroke distance (d). Best swimmers could maintain higher (d)-levels throughout the exercises as compared with their inferior counterparts. It is advised to check individual (d) –values when testing the aerobic/anaerobic transition zone since d(max) match (in most cases) “with the approximate area of transition from aerobic to anaerobic metabolism”.

Nomura & Shimoyama (2003) investigated the “stroke length” (there is no information whether it was calculated or measured) during step test at different flume speeds and compared the data with speed at blood lactate of 4 mmol/l and speed at lactate threshold (speed at lactate threshold is less than the speed at blood lactate of 4 mmol/l). The data of 12 well trained freestyle swimmers revealed that the displacement increased with increasing speed but at 65-70% of personal best time of 200 m freestyle the displacement decreased. The point of decrease (stroke-length-peak-point) corresponds to speed at lactate threshold as well as to the speed at blood lactate of 4 mmol/l but not to the personal best time. It was suggested that that stroke-length-peak-point would correspond to endurance capacity. It is recommended to determine the speed of stroke-length-peak-point individually because this speed represents the right training intensity to improve endurance capacity without acidosis.

REFERENCES

Craigh, A.B., Boomer, W.L. & Gibbons (1979). The use of stroke rate, stroke distance per stoke and velocity relationsships during training for competitive swimming. In: J Terauds & W. Bedingfield (eds.) Swimming III. University Park Press, Bltimore: 265-274.

Haliand, R (2007). Competition Analyses. Retrieved 26. 12. 2007 from http://www.swim.ee/

Hill, A.V. (1950). The maximum work and mechanical efficiency of human muscles and their most economical speed. J. Physiol. 56:19

Keskinen, K. (1997). The relation of fatigue on stroking technique. . In: B. O. Eriksson & L. Gullstrand (eds.) Proceedings XII Fina World Congress on Sports Medicine. Göteborg:330-334

Nomura T., Shimoyama Y. (2003). The relation between stroke parameters and physiological responses at various swim speeds. In: J C Chartard (ed.) Swimming IX. University of St. Etienne, 355-360.

Toussaint H-M, Hollander A.P., Groot G., van Ingen Schenau G. J., Vervoorn K., de Best H., Meulemans T., Schreurs w. (1988). Measurement of efficiency in swimming man. In: B.E. Ungerechts, K. Wilke, K. Reischle (eds.) Swimming Science V, Human Kinetics Books, Champaign: 45-52.

Ungerechts, B. (1979). Über den Wert der Zugzahl-Ermittlung in swimming (The value of measuring of the stroke rate in swimming). Leistungssport, 5: 353-356.

Ungerechts B.E. & Thiesmann, M. (1995). Changes of stroke rate during swimming races. In: K. Häkkinen, K.L. Keskinen, P. Komi, A. Mero (eds.), XVth Congress of the International Society of Biomechanics -Book of Abstracts-, 946-947.

Wirtz, W., Bieder, a. & Wilke, K. (1997). Kinematic aspects of training devices in the supramaximal crawl sprint. In: B. O. Eriksson & L. Gullstrand (eds.) Proceedings XII Fina World Congress on Sports Medicine. Göteborg: 380-388.

Aquatic Space Activities – Praxis needs Theory

Bodo Ungerechts[1], Jürgen Klauck[2]

[1] University Bielefeld, Department Neurocognition and Action – Biomechanics, Germany

[2] German Sport University Cologne, Germany

Aquatic Space Activities (ASA) is an umbrella-like term for activities in water like: Competitive – Recreational – Masters swimming, Fin-swimming, Triathlon, Scuba-diving or Water-exercises. ASA have to obey flow physics. Traditionally, flow physics in aquatic sports is confined to steady conditions assuming that the flow velocity is constant and the body is rigid. It is not new information that this is not and was never the case in human swimming. Fact is, limbs change motion in all ASA which cause unsteady flow conditions. Unsteady flow demands closer consideration of water-motion induced by limbs' motion. The purpose of this paper is to introduce some challenging information concerning unsteady flow conditions and consequences for practise.

Key words: *unsteady flow, momentum-induced propulsion, jet-flow*

INTRODUCTION

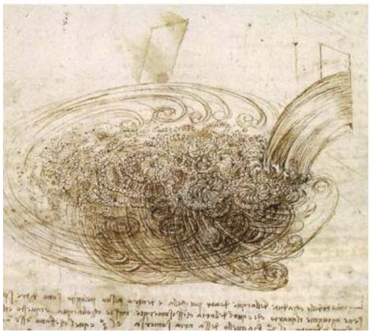
Aquatic Space Activities (ASA) is focusing attention on the interaction between actively moving body (or its parts) and water-mass set in motion. ASA deals with the mutual effects of buoyancy and the reaction to induced water-motion. Buoyancy is a natural reaction due to displacement of water-mass of any body, resting and submerged in water. Induced water-motion or water flow is a physical reaction due to displacement of water-mass of any submerged body moving relative to the surrounding water.

Reactions to induced water-motion have some contra-intuitive features. Simple drag approach suggested by most books on swimming does not explain swimming speed sufficiently. Hands' actions are not most effective if water resistance is at a maximum (the term effective is focusing on the result of an action). The intuition may tell that e.g. a hand is moving the same block of water either back or moving new blocks by changing hand motion is not the complete story. What really happens will be (completely) different. According to the law conservation of mass, in a flow water cannot be pushed away in relation to the surrounding water-mass. Nevertheless it is true: where there is one solid body (like a swimmer's hand) there cannot be another body. However, where the mass of displaced water is going to?

Since long it is decided that aquatic space is characterized like a body by mass and other features. Firstly, water has the property to change shape. Any body, e.g. hand or leg, even when moving relative to water displaces some water-mass. This means the motion of water (in the vicinity to the moving body) is changed and a flow is created: if water is at rest (before it is displaced) the sentence is also true: what counts is the relative change of motion. Since the relative motion between body and water is essential, research about aquatic activities executed in a flume applies to activities in a pool. The aim of this paper is an introduction to some facts of flow physics, beyond existing biomechanical aspects, relevant for a better understanding of mutual aspects concerning aquatic space activities and reaction of water-set-in-motion.

Features of aqua at rest and in motion: Pressure is an important feature. When a body, resting and submerged in water the weight of the displaced water-mass excerts a force due to water pressure in upward direction, called buoyancy. A body, submerged and moving relative to water produce a change of pressure and due to that change "some" particles are set into motion. Based on the continuity-pressure-concept the pressure cause and maintain a flow, a continuous movement of a fluid from one place to another. According to *Euler* (1707 -1783) particles-in-motion (i) possess masses, weights, accelerations, velocities, etc. and (ii) occupy some space in the vicinity of the moving body (whereas the rest of water-mass remains undisturbed).

This space of particles-in-motion is full of vectors and scalars, forming vector fields.



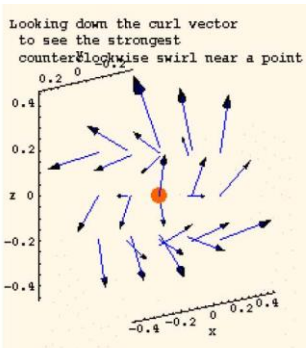


Fig 1 flowing water: sketch of Leonardo Da Vinci today: **cm.math.uiuc.edu/242syl.php**

A unique feature of these vector fields: they allow for transitional and rotational motions of the particles (the particles itself do not rotate, but follow a circular path), indicating that vortex forms and effect induced by vortex forms are likely. By independant variations in time and in space the flow is to a certain extend "unpredictable" (also when the displacing action is causing "un-steady" flow conditions). From practical experience it is known that swimmers claim they sometimes fell a "different slip" although using the same biomechanical actions.

Between particles exists an internal friction, measured as viscosity, which is the cause of pressure change. The change of pressure is mediating between any displacing action of any body and particles-in-motion; hence, interaction of limbs and water-mass means pressure-change. In addition, viscosity causes repulsive actions. The reaction to this repulsive action is mostly measured by the established u^2-law of resistance – provided – the flow remain unaffected by any body (called steady situation).

Momentum-induced propulsion in Aquatic Space: Propulsion, the act of displacing a total body in aquatic space, is related to a change of motion of water-mass. The change of motion of any mass is called *momentum*. Galileo (1565-1642) already pointed out that *momentum* is the property by which the motive agency moves and the body resists. Newton (1642-1727) claimed, displacement means departing *momentum* to all particles set in motion. *Momentum* is a vector: the magnitude is the product of mass (m) times its velocity (v): [m*v] = kgm/s = Ns and its direction coincides with the direction of the velocity.

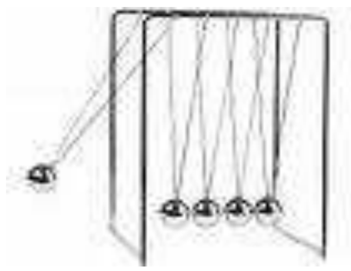


Fig 2 Pendulum object to demonstrate momentum transfer

The *momentum* approach allows for application of the law of conservation of *momentum* (original enunciation: René Descartes (1596-1650). According to this principle the total *momentum* is constant – provided a closed system is considered (which is not subject to external influence). If two (or more) masses belong to a closed system (Fig. 2) and one mass changes velocity, simultaneously the other masses will adapt their *momentum* (in opposite direction), hence, any interaction between body and surrounding water gives a reaction. Actions of (parts of) any body in aquatic space are transmitting energy while changing the motion of water-mass over a period of time. The simultaneous reaction has effects in and against swimming direction at the same time. If increasing speed of a total body is observed, it means “netto” effects in swimming direction.

The principle of momentum claims that if the momentum before and after an interaction of limbs and water-mass differs this difference is induced by the interaction. This concept is elegantly applied to determine effects of a “displacing” rigid total body on a flow of constant speed, eiher in steady or unsteady conditions. Based on the law of conservation of *momentum* it is evident that *momentum* in front of the total body must be equal to the momentum in the wake *plus* all momentum changes produced by the interaction between total body and particles-in-motion. The difference of *momentum* over time in steady flow is called drag or propulsion (Fig. 3).

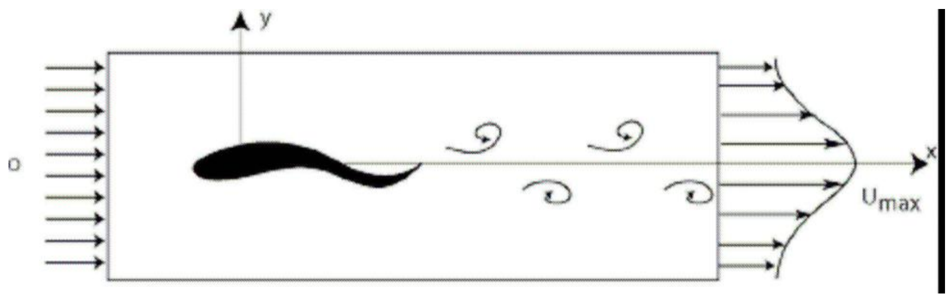


Fig. 3 Momentum change due to the total body action of the fish resulting in thrust

Jet-propulsion in aquatic space: In context with induced water motion it was pointed out that body actions change motion of water-mass due to interaction of limbs and water-mass. The effect of interaction of limbs and water-mass is a change of *momentum*. From this it follows that the change of momentum of particles (m’*v’) are combined with a change of momentum of the total body mass (m’’*v’’), in opposite direction. From the swimmers view the reaction (m’’*v’’) provides components in and against swimming direction (is called drag or thrust). If momentum of particles (m’*v’) is totally directed against swimming direction of the total body, the reaction results in

100 % effects. If water moving backwards is thrusting a total body forwards. However, this does not “say” move your hand or leg backwards to gain an effective thrust.

The most effective and efficient way to gain maximum of thrust for a given energy-input is a jet-flow, like used by squids or jelly fish (Fig . 4).

Fig. 4 Vortex induced jet by a jelly fish

Jet-flow is a powerful stream of mass carrying high momentum. Jet-propulsion is existing also in swimming of skilled human. Matsuuchi, Miwa and Ungerechts (2004) published research data based on PIV-method, Particle Image Velocimetry, demonstrating the existence of intermittent jet-flow. Close scrutiny revealed that first a vortex-ring had to be produced by the action of the swimmer’s hand in its wake. The rotation of the vortex rings cause a particle drift in one direction; the shape and rotation of the vortex ring determines the jet length-to-diameter-ratio and thus the *momentum*. Hence, the orientation of the jet-flow relative to swimming direction is determining the contribution to thrusting the body.

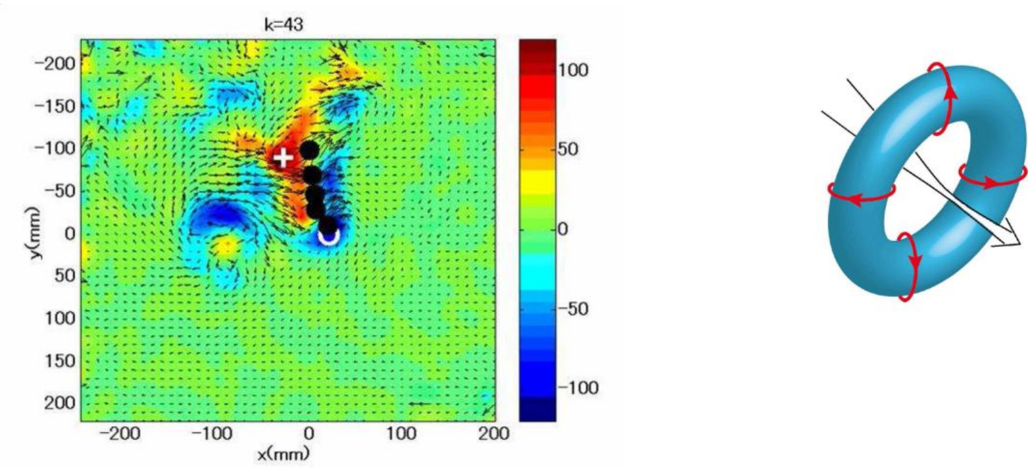


Fig. 5 Vortex-induced jet-flow of a hand while swimming freestyle

DISCUSSION

The concentration on the interaction of limbs and water-mass instead of limiting oneself to the mere action of limbs or bodies is part of augmenting the cognition of reality. The act of cognition is a continuing process and prone to verification / falsification of theories. The saying, nothing is more practical than a good theory, is valid when theory mirrors reality. Sometimes a change in theory means that already existing, but not established concepts survive; e.g. Berger (1996, 95) found that high propulsive forces cannot be based on lift and drag of an acting hand solely and concluded “the key to producing effective propulsion at low energy cost may be a creation of vortices of a special form”.

The research of the jet-flow requires a water-related view of both the locomotion of the limbs and of the water-in-motion in aquatic space. Most of the existing studies on swimming are using a body related approach focussing on the velocity of body actions. In most studies related to swimming the movement of the surrounding water is limited to lift and drag approach, established in 1970 by Counsilman. Already in 1986 Counsilman claimed in personal communication: “I can’t help it if people still refer to my publications of the end of the sixties”. He was aware that the drag and lift approach was not applicable to unsteady swimming situation. In that time the vortex induced propulsion concept and influence of added mass to swimming bodies started to attract the interest of (few) swimming researchers. Ungerechts (1988) published an idea that breaststrokers’ leg actions lead to rotating water forms by which “momentum is transferred to the fluid and in reaction, its “impulse” accelerates the body.” Tilborg et al. (1988) presented data of “impulses”, measured in Ns, resulting from the difference between propulsion and resistance for different phases in breaststroke; they pointed out that “impulses are more reliable than forces”. Ungerechts (1992), calculated momentum needed to change hip motion (Δv) during arm stroke including an inertial term due to acceleration based on experimental data of eight breaststroker and compared the data with forces due to hands’ actions; it was shown that momentum =|16,5 – 45,9| Ns will explain (Δv) = |0,27 -0,76| m/s with 93 % confidentiality. Ungerechts & Klauck (2006) presented the flow physical laws which are relevant for unsteady flow in conjuction with added mass effects. Practical implications: The increase of knowledge of effects of ASA in the last decade is remarkable and resembles a change in paradigm. The traditional paradigm is body orientated and concentrates on the biomechanical aspects of body motion. ASA related sports like Recreational swimming, Fin-swimming, Triathlon, Scuba-diving or Water-exercises seems to be far from this water related view, still are relying on established u^2-law of resistance. It is a legal pedagogical view, looking for solutions how to teach swimming and stroking correctly. Bridging the gap and approach a water related view including unsteady features of flow seems to be very hard.

A change of paradigm from body related to water related view is considering the effects due to displacement of water besides some repulsive effects. The latter are not neglected but qualified. Being aware that humans can perform well in aquatic space without knowing details of flow physics it is not the same when instructors or coaches are not well informed about the relevancy of interaction of limbs and water-mass and its reaction. In particular the illiteracy of the momentum aspect, about ten papers in the Conference Series of Biomechanics and Medicine of Swimming 36 years were handling this topic, is not helpful.

The water related view is also tackling the terminology of rules of stroking written for the referees in swimming. The terminology still uses the concept of pulling and pushing arms, whereas e.g. the BMS conference series revealed that sculling actions are dominating all strokes. Of course each expert is free to select the terminology. But a more appropriate terminology is supporting mental representation of strokes, required to execute movements.

A vortex-ring like structure by hand-action demands a turning around action of the hand, like supination or pronation, during the period of underwater action. Since all sports belonging to ASA will face the effects more or less, it is concluded that unsteady flow physics should become the basis of further research, independent if a biomechanical or physiological issue is studied.

REFERENCES

Berger M (1995). Force generation and efficiency in front crawl swimming. Thesis Vrije Universiteit, Amsterdam.

Matsuuchi K, Miwa T, Nomura T, Sakakibara J, Shintani H, Ungerechts BE, 2004. Unsteady flow measurement around a human hand in swimming using PIV. In: E v Praagh, J Coudert, N Fellmann, P Duché (eds.) Proceedings of 9th Annual Congress of the ECSS, Clermont-Ferrand, 274.

Tilborgh van, L, Willems E.J, Persyn U. (1988). Estimation of breaststroke propulsion and resistance-resultant impulses from film analyses. In: B.E. Ungerechts, K. Wilke and K. Reischle (eds.), Swimming Science V, Human Kinetics Publishers, Champaign, IL: 67-71.

Ungerechts, B.E., 1988. The relation of peak body acceleration and phases of movements in swimming. In: B.E. Ungerechts, K. Wilke and K. Reischle (eds.), Swimming Science V, Human Kinetics Publishers, Champaign, IL: 61-66.

Ungerechts, B.E., 1992. *The interrelationship of hydrodynamical forces and swimming speed in breaststroke.* In: D. MacLaren, T. Reilly & A. Lees (eds.), Biomechanics and Medicine in Swimming -Swimming Science VI-. E. & FN Spon, London:69 -73.

Ungerechts B. E., Klauck J. 2006. Consequences of non-stationary flow effects for functional attribution of swimming strokes. In: J.P. Vilas-Boas, F. Alves, A. Marques (eds.), *Biomechanics and Medicine in Swimming X*. Portuguese Journal of Sport Sciences, Vol. 6, Suppl. 2, 109-111.

ACKNOWLEDGMENTS

The authors would like to thank Dr. Huub Toussaint from Swimming Research Center Amsterdam, The Neteherlands, for valuable information and suggestions to accomplish this paper.

A STUDY FOR CHANGING ASPECTS OF WATER POLO GAMES DUE TO THE CHANGES IN INTERNATIONAL RULES IN 2005

Nobutaka Shimizu[1], Hideki Takagi[2]

[1]University of Tsukuba, Faculty of Health and Physical Education, Japan

[2] University of Tsukuba, Faculty of Comprehensive Human Science, Japan

The purpose of this study is to evaluate the aspects of the games such as swimming distance, swimming velocity and time-motion analysis under a revised condition. The activities of 18 water-polo-players（6 center forwards, 6 drivers and 6 center backs）were videotaped and analyzed, in a total of five games of the Japan Swimming Championship which was held in the Tokyo Metropolitan Gymnasium from 29th June to 1st July in 2007. As results, an average of game duration was 48min 53second. An average of swimming distance of total is 1803.3±137.8m. An average of swimming velocity of total is 0.65±0.06m/s. It is revealed that the mean duration of contact was decreased, the mean duration of swimming was increased and the mean duration of vertical position was decreased. These results show that the intention with the revision of rules has been achieved.

Key words : *water polo, swimming distance, swimming velocity, time-motion analysis*

INTRODUCTION

The FINA (Federation Internationale de Natation Amateur) has changed the international rules of water polo to make the water polo more attractive globally in 2005. Up to that time it was said that following problems had been preventing the water polo from developing worldwide, e.g. a lack of a sense of speed, a lack of goal opportunity, etc. To solve these problems the FINA has decided to revise the international rules such as following essential features, i.e. an increase of game duration (7min to 8min), a decrease of attacking time (35sec to 30sec), etc. The Japan Swimming Federation has adopted the revised rules since 2006. Although a major change was expected in aspects of the games by adopting the revised rules, a verification how changed has not been done yet. Therefore, the purpose of this study is to evaluate the aspects of the games such as swimming distance, swimming velocity and time-motion analysis under a revised condition.

METHODS

The activities of 18 water-polo-players（6 center forwards, 6 drivers, 6 center backs） were videotaped and analyzed, in a total of five games of the Japan Swimming

Championship which was held in the Tokyo Metropolitan Gymnasium from 29th June to 1st July in 2007. A two-dimensional DLT method was used to evaluate a position of player, swimming distance and swimming velocity by the Fame Dias II (DKH Cooperation). In addition the time-motion analysis was done to evaluate the game qualitatively.

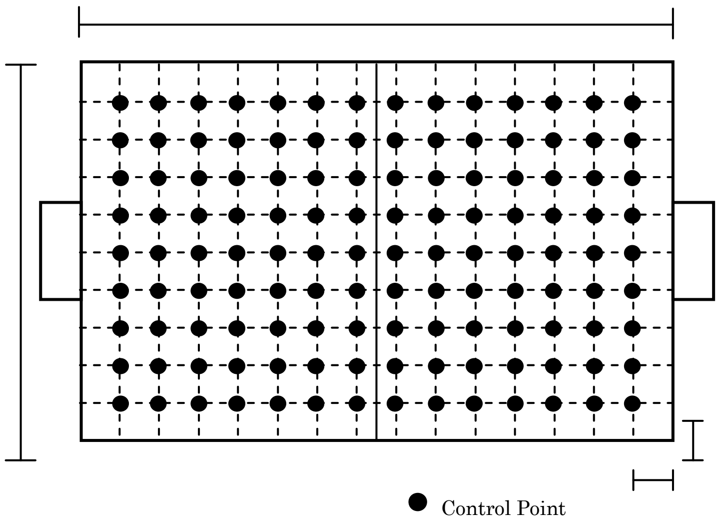


Figure 1. A size of water polo game field and the control points for caribration

RESULTS& DISCUSSION

Game Ⅰ is 53 min 07 sec, game Ⅱ is 45 min 18 sec, game Ⅲ is 52 min 23 sec game Ⅳ is 47 min 16 sec, game Ⅴ is 46 min 23sec. Average of game time is 48 min 53 sec. Mean of game time increase more then old rule game (Takagi,1987). This result is thought to be due to an increase of the game duration.

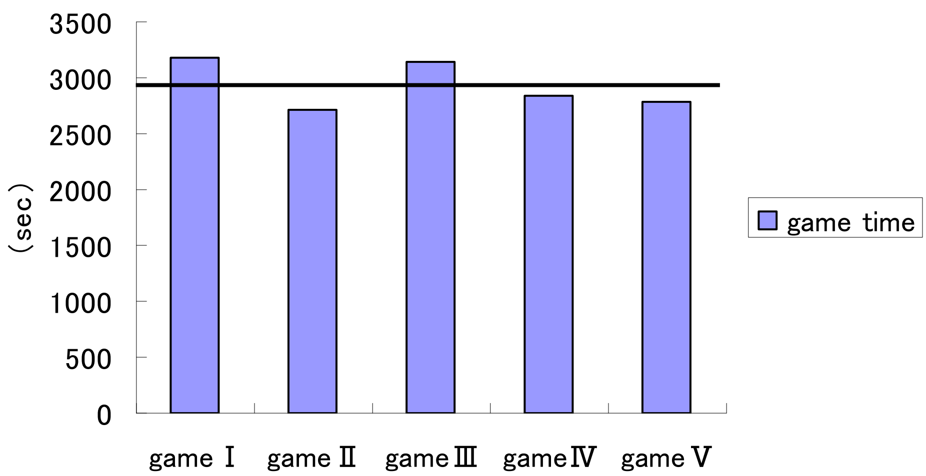


Figure 2. Length of a game

Swimming distance of 'center forward' is 1764.6±102.0m, 'driver' is 1941.7±82.3m, 'center back' is 1718.5±118.6m. Mean of swimming distance is 1808.3±137.8m. 'Center forward' and 'driver', 'driver' and 'center back' differ significantly in swimming distance. Swimming distance increase more than old rule games (Takagi,1987; Komori,1999). This result is thought to be due to an increase of game duration and turnover is increased by a decrease of attacking time. An increase of turnover solved a lack of a sense of speed

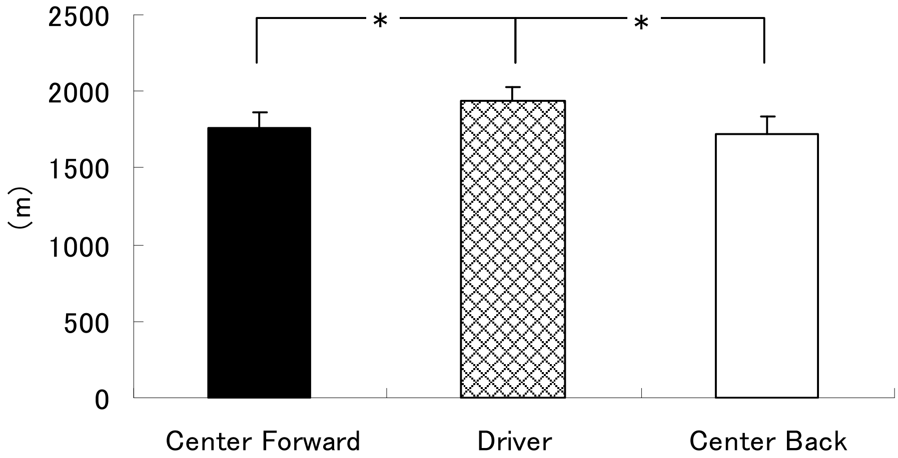


Figure 3. Swimming distance *(p<0.05)

Swimming velocity of center forward is 0.66±0.07m/s, driver is 0.66±0.04m/s, center back is 0.63±0.08m/s. 'Center forward', 'driver', and 'center back' not significantly different in swimming velocity. Swimming velocity doesn't change old rule games(Tubakimoto,1986; Takagi,1987; Komori,1999).

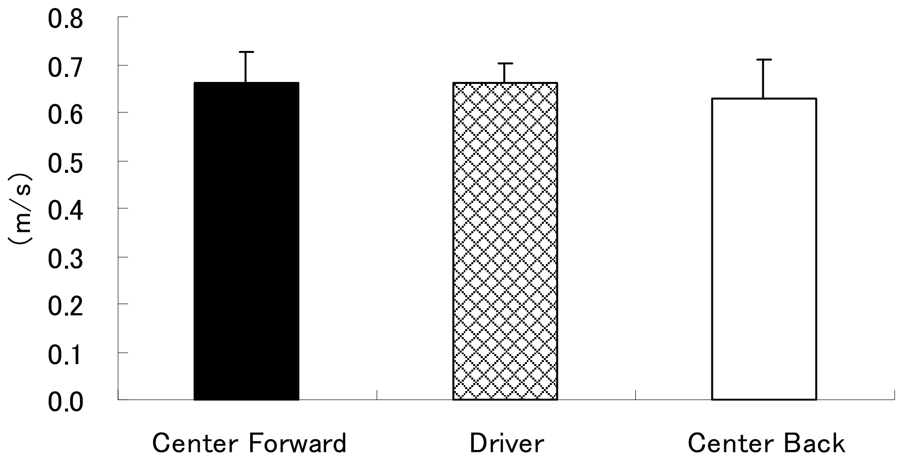


Figure 4. Average swimming velocity during a game

Relative frequency of swimming velocity is Stop (0.00～0.09m/s) 3%, Low velocity (0.1～0.89m/s) 69%, Middle velocity (0.9～1.69m/s) 29%, High velocity (1.7～2.4m/s) 1%. Stop decrease more than old rule(Tubakimoto,1986;Takagi,1987). Low velocity, Middle velocity, and High velocity don't change. A decrease of 'Stop' solved a lack of a sense of speed.

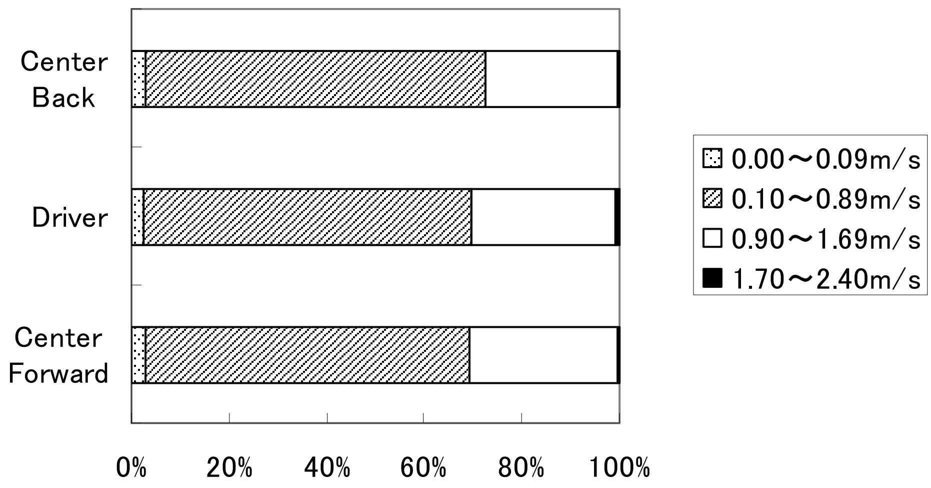


Figure 5. Relative frequency of swimming velocity

The most frequent range of the swimming velocity is 0.2～0.3m/s. After it decrease until 0.7m/s, and it keeps until 1.3m/s. It doesn't change the most frequent range of the swimming velocity is 0.3～0.4m/s in old rule game(Takagi;1987).

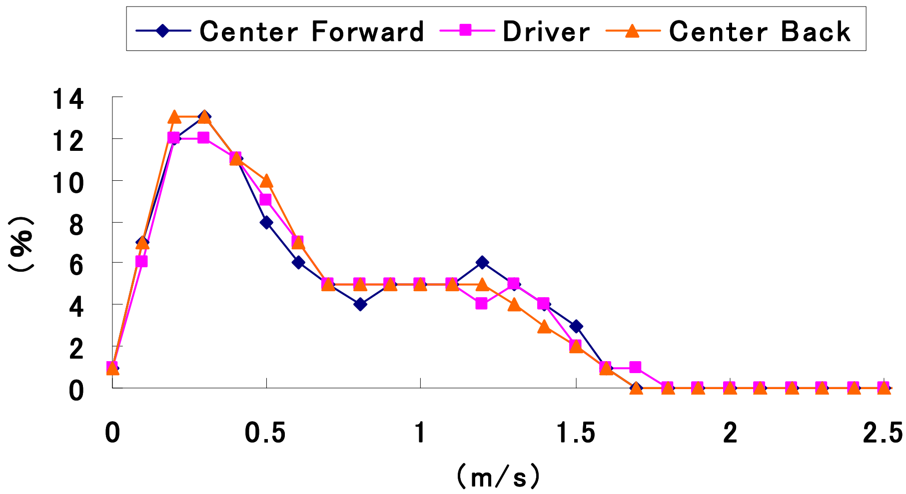


Figure 6. Frequent range of the swimming velocity for each position

Although a moving trace of center forward is focused center of coat, the driver's trace spread all coat. While a moving trace of center back is focused back coat. They don't change old rule(Tubakimoto,1986; Komori,1999).

Mean duration of contact was decreased, while mean duration of swimming was increased. Therefore, hard contact is said to be decreased. This result is thought to be due to a decrease of attacking time. And it solved a lack of a sense of speed.

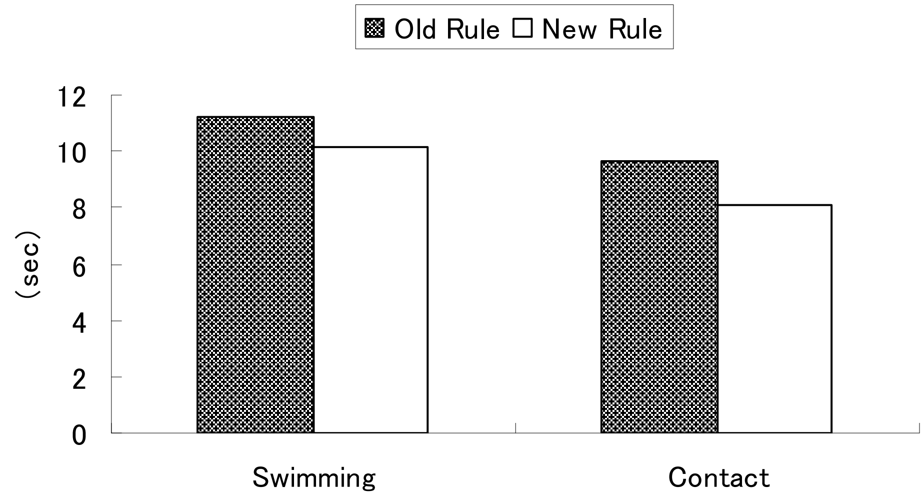


Figure 7. Mean duration of swimming and contact phase

CONCLUSION

Maximum swimming distance is 2040.6m by drivers. Minimum swimming distance is 1499.2m by center back. Mean of swimming distance is 1808.3±137.8m. Swimming distance increase more than old rule games. The most frequent range of the swimming distance is 1.1～1.3m/s. Therefore, training menu for swimming is 400~500m on 1 set. Total distance is about 2000m. For example, limited time is 1:15～1:30 in 100m. It spends less contact times. Therefore, decrease of hard contact run on developing worldwide. Vertical body displacement decrease and swimming times increase solved a lack of a sense of speed. As a result, audience can enjoy game and rule amendment is success.

REFERENCES

1) Hideki TAKAGI（1987）：Game Analysis of Waterpolo Studies on Moving Distance and Velocity during the 85’KOBE Unversiade Games, The proceedings of the master thesis in University of TSUKUBA, 93-96.

2) Shozo TSUBAKIMOTO（1986）：A Game Analysis of Water Polo-about swimming distance, moving trace, and swimming velocity. The bulletin of University of IBARAKI, 19：231-241.

3) T.PLATANOU（2004）：Time-motion analysis of international level waterpolo players. Journal of Human Movement Studies, 46：319-331.

4) Yasuka KOMORI（1999）：Character of water polo for swimming distance. 50th Japan Society of Physical Education, Health and Sport Sciences：847.

A study on effects of the training aimed at improving a speed of shooting in water polo

Hirofumi Funasaki[1] , Hideki Takagi[2]
[1]University of Tsukuba, Master's program in health and physical education, Japan
[2]University of Tsukuba, Institute of Health and Sport Sciences, Japan

The purpose of this study was to estimate effects on shooting speed by eggbeater kick's training and weight training that are supposed to effect on shooting speed. In addition, it will explain what physical and technical factors relate to shooting speed. Eighteen members of Japan men's university water polo team participated in the study. The eleven players belong to the training group and other seven players belong to the control group. The former is regarded as the training group which performs the effect of special training that was proven in the pilot study.
The special training consisted of an underwater training using a tube and a weight training for specific body parts. On the other side, the latter is regarded as the control group, they didn't carry any special training but normal training. As results, after they worked out their respective training, we found that both of them improved their shooting speed. The training group significantly stepped up to 2.2km/h (p=0.016) while the control group did to 1.4km/h (P=0.0008). Moreover, we found that the wrist curl related to physical factors and a height of the right elbow and the right toe related to technical factors. Those are, however, only confirmed in the training group. Therefore, it is allowed the special trainings in the experiment were valuable.
It was also found that the enforcement of the wrist curl and the height of dominant side's toe and elbow were important to improve shooting speed. Moreover, improvement of eggbeater kick is essential in order to raise the height of dominant side's toe.
Key words: *water polo, shooting speed, eggbeater kick, muscular strength, multiple correlation*

INTRODUCTION

Recently level of Japanese water polo has been improving. That is because of consistent training of players from junior and environment that players keep playing after graduation from a university. However, they couldn't be a champion although they were placed the 2nd in Asian Games 2002 and 2006, which seems be far away from the level of national competition. Then, the crucial problem of the reason why our team can not

win in Asian Games and national competition is low ability of scoring (Hashiratani et al. 2005). Besides there are many reasons such as the ability of passing, judging situations, foot work, contact play and so on. Especially, the Japanese team is inferior in ability of shooting compared to other countries. Therefore, it is difficult for Japan to get a prize without improvement of shooting ability. Although there are many factors to improve shooting ability, we focused on shooting speed in this study. The rule was widely changed in 2005. From then players can shoot from 5 meters away from goal line while they could 7 meters. This change effected on importance of shooting speed to get score. Regarding improvement in shooting speed in water polo, many studies have been done through measuring speed and analyzing forms. However, not many of those studies have shown their effect in fact yet. According to Funasaki (2006), it is shown that shooting speed related to an eggbeater kick ability. Then, methods of training and shooting form to improve shooting speed are needed to be reform as soon as possible.
The purpose of this study was to estimate effects on shooting speed by the eggbeater kick's training and the weight training that are supposed to effect on shooting speed. In addition, it will explain what physical and technical factors relate to shooting speed.

METHODS

Eighteen members of Japanese men's university water polo team participated in the study. The eleven players belong to the training group and other seven players belong to the control group. Measuring and filming were done twice during season before May and after September. We measured shooting speed, body measuring, muscle measuring and three-dimension analysis. To find factors to improve shooting speed, a correlation analysis and multiple correlation analysis were carried out between shooting speed and other measuring items regarded value less than 5% as significant. A tube training and the weight training were carried out, which were supposed to effect on shooting speed into the training group. On the other side, any special training weren't carried out but normal training into the control group.

Figure. 1 Eggbeater's training with rubber tube

RESULT AND DISCUSSION

After they worked out their respective training, both of them improved their shooting speed. The training group stepped up to 2.2km/h ($P<0.016$) while the control group did to 1.4km/h ($P<0.0008$). Compared to control group, training group improved more (3.3% vs 2.1%). Although their speed was worse 0.3km/h in pre-test, it became better 0.5km/h in post-test (Fig.2-3).

For the anthropometric measurements in the only training group, they significantly improved only gluteal girth from 91.3cm to 92.9cm ($P<0.013$) among 15 items. It is thought that most items didn't improve because measuring was taken place after the season. It is suggested that training group improved the gluteal girth significantly because they practiced eggbeater's training with rubber tube during the season. Although it is also effect of weight training, most items didn't improve or became worse. It is appropriate to consider the effect of eggbeater's training.

In the measurement of muscular strength, in the only training group they got effect of wrist curl($P<0.048$) significantly. According to Funasaki(2006) it is reported that enforcement of the wrist muscle is important to improve the shooting speed. In major water polo countries, e.g. Hungary and Serbia, they necessarily practiced the wrist curl to enforcement of the wrist muscle. A snap which is the last part of shooting enable to accelerate speed toward ball and make faster shooting. Therefore it is suggested that the wrist curl training that was given in training group got effect and improved their shooting speed. Moreover Miyagi (1986) reported that there was a correlation between shooting speed and grip. Although it is not confirmed that wrist curl training correlate directly enforcement of a grip strength, it is assumed that it correlate indirectly enforcement of the grip strength. Feltner and Nelson (1997), however, reported that large amount of muscle and joint torque are necessary for using overhand throw. Therefore, they also indicated rise of injury risk. So, not only enforcement of wrist muscle by the wrist curl but also an enforcement of other parts of muscle needs to be done. Otherwise it is not expected to improve the shooting speed, what is worse, to fall performance by injury.

The height of measuring point (upper body) on the release time was improved significantly in training group; right elbow, right wrist, left wrist and right hand. On the other side, in control group; vertex, right shoulder, right elbow, left elbow, right wrist, left wrist, right hand and left hand. It was suggested that on the release time the fact the height of measuring point (upper body), especially elbow, wrist and hand improved in both groups effect on the shooting speed. It is thought that the training group improved more than the control group because height of right elbow, right wrist and right hand are superior to the control group. If players can get their upper body out of water, their upper body can move freely. The position of upper body as high as possible are considered to improve the shooting speed.

The height of measuring point (lower body) on the release time was improved significantly in training group; right trochanter major, left trocanter major, right knee, left knee, right ankle, left ankle, right heel, left heel, right dorsum pedis, left dorsum pedis and right toe. On the other side, in control group; right trochanter major. It was suggested the height of measuring point (lower body) on the release time, especially right knee, ankle, heel, dorsum pedis and toe which are used for start part of kicking, significantly improved. In pre-test at the start part of kicking right foot stretched out while in post-test it kept higher position. In short, it is suggested that to start kicking with foot higher position is important. According to Funasaki (2006), there is a correlation between the shooting speed and the eggbeater ability. Also Susa (2007) reported that the height of trochanter major and knee related to the shooting speed.

In training group the wrist curl and the hand girth as physical factor and the height of right toe, dorsum pedis, ankle, heel and elbow related to the shooting speed concerning on the release time. A correlation between the wrist curl and the shooting speed corresponded to the report of Funasaki (2006). Also Miyagi (1980) reported that if players can grip the ball, they can throw faster. Takagi (1990) reported that if players can not grip the ball, they can't throw faster like baseball player. Also Arakawa (1971) reported that in handball hand girth and force of grip effect on shooting speed. From those reports it is assumed that the hand girth effects shooting speed to some extent. However, even if the hand girth is insufficient, it is assumed to cover enforcement of grip like a investigations.

As a result of multiple correlation analysis of shooting speed and each measuring items, a significant correlation with shooting speed was found in the only training group. It was suggested that the wrist curl as physical factor and the height of right toe and elbow at the release time effected on shooting speed. If players can raise toe's position, they can raise their lower body necessarily. It is also said to be the same thing for the upper body. For those results it is suggested that a stability and raising of lower body can improve shooting speed.

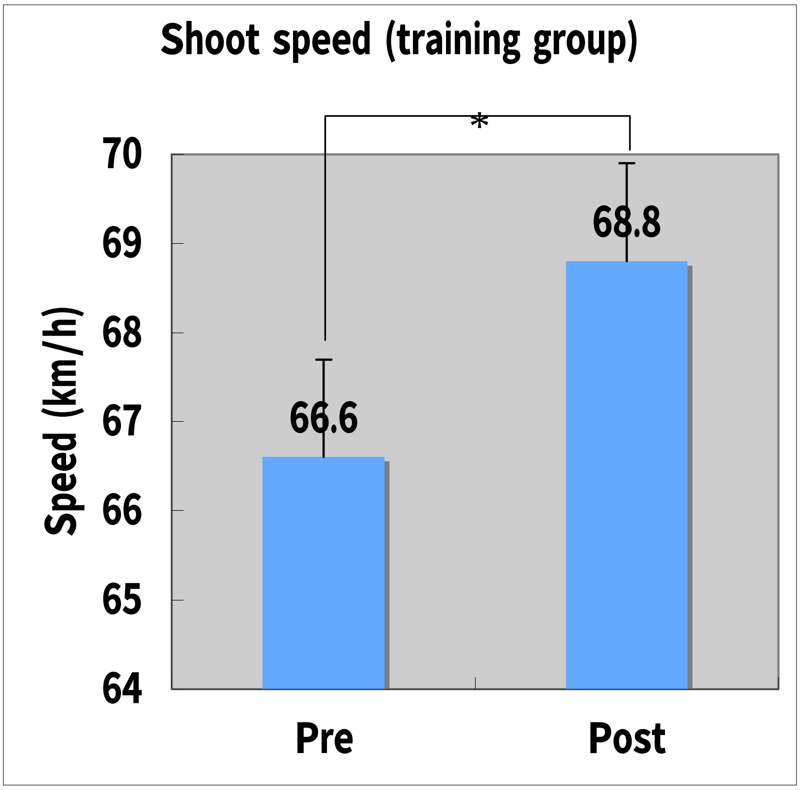


Figure. 2 Shoot speed of training group

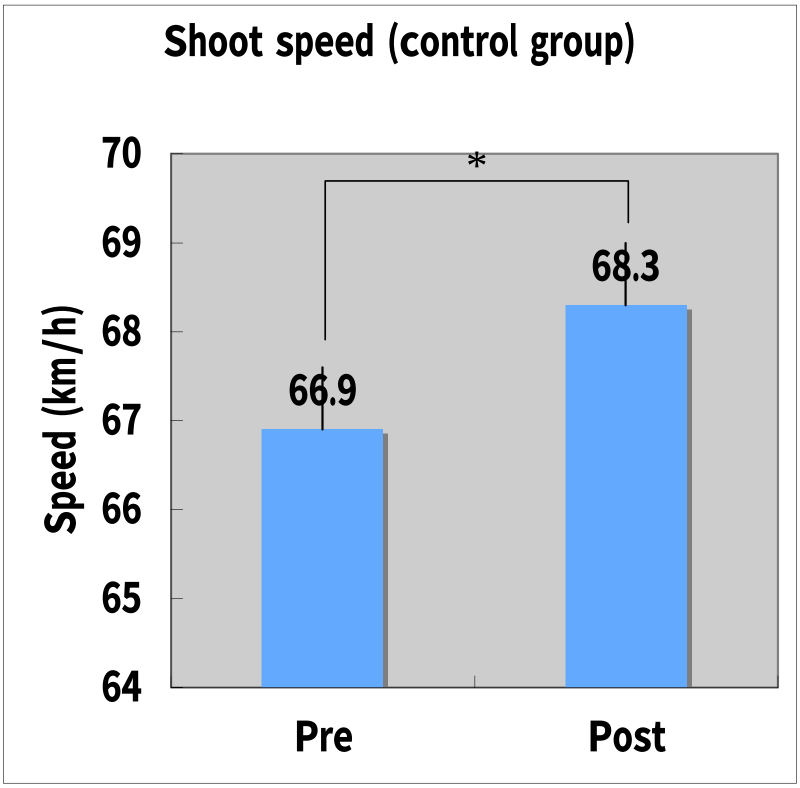


Figure. 3 Shoot speed of control group

CONCLUSION

It was found that the enforcement of the wrist curl and the height of dominant side's toe and elbow were important to improve shooting speed. Moreover, an improvement of eggbeater kick is essential in order to raise the height of dominant side's toe. Therefore, we analyzed into the effect of eggbeater kick's training with a rubber tube.

REFERENCES

Michael E. Feltner and Grant Taylor (1997) : Three-Dimensional kinetics of the Shoulder, Elbow, and Wrist During a Penalty Throw in Water Polo. JOURNAL OF APPLIED BIOMECHNICS 13 : 347-372

Hirofumi Funasaki (2006) : Factors to improve the shooting speed in water polo. The 6th International Swimming Reserch Symposium, University of Tsukuba, [in Japanese]

Hideki Takagi, Masanobu Honma, Michiyoshi Ae, Masaaki Suga (1990) : The three-dimensional analysis of the water polo shot. Biomechanical Research 90. Medical Press: Tokyo, pp.261-26

A Study of shot speed in water polo

- The date of the speed gun in 12th FINA World Championships -

Masaaki Suga[1], Takahisa Minami[2], Satoshi Kawakami[3], Nobutaka Shimizu[4]

[1] Oita Prefectural College of Arts and Culture, Japan

[2] Naruto University of Education, Japan

[3] Nippon Junior High School Physical Culture Association, Japan

[4] University of Tsukuba, Faculty of Health and Physical Education, Japan

The purposes of this study are to classify goals in the 2007 FINA World Championships Water Polo games and to verify the shot speed which was measured with a speed gun. The speed of 171 shots was collected and analyzed by the attack pattern and the shot area.

It follows from these analyses that the fastest average shot speeds were recorded in the case of the penalty shot (74.7 kph), the middle shot (68.7 kph) nearby, the 5m shot (71.2 kph) and the middle shot in extra-man (67.1 kph). The shots of these attack patterns were taken by a similar standing posture.

Furthermore, a faster shot speed was recorded in the 5~10 meter area from the goal line and near the vertical line to a goal.

Key words: *Water Polo, Shot speed, Speed gun, FINA World Championships*

INTRODUCTION

Water polo is a sport with the aim to score by swimming, passing, dribbling a ball and shooting to the opponent goal in the field of 30 by 20 meters in size. The shot for scoring needs the elements of speed, control and timing. As for speed, it is an advantage for scoring to shoot a fast ball as the goalkeeper can't react to the shot. Up to the present moment, there have been many research studies about the shooting motion in Water Polo, and the initial ball speed was measured with the analysis of it. According to Takagi's reports [1)] about the former analysis of Water Polo shot, the initial ball speed for men's player was about 20 meter per second (72 kph), and the maximum speed was 24.5 meter per second (88.2 kph) which Darras [2)] analyzed for the players who participated in the FINA World Cup.

As for the former research, a shot speed was analyzed by the video analysis. On the other hand, measuring a ball speed is frequently done by a speed gun recently.

In the FINA World Championships Water Polo games which were held in March 2007 in Melbourne, Australia, the shot speed was displayed on the screen at the venue for the first time through the Olympic Games and the World Championships. In this event, a total of 925 goals were scored. It is very interesting to collect many shot speed data of top level players in real games. Also, even though the speed gun manufacturer admits an accident error in the case of measuring the shot speed from a diagonal direction, there are a lot of shots from the diagonal direction in real games.

Therefore, the purposes of this research are to classify goals in the FINA World Championships Water Polo games and to verify the shot speed which was measured with the speed gun.

METHOD

In the FINA World Championships (48 games for men), the technical staff of the Japanese Water Polo Committee videotaped the games. The shot speed data of 171 goals which can be checked on the screen at the venue was collected from the videos of the games. These data were classified by the attack pattern and the shot area, and an average shot speed was calculated in each attack pattern and shot area.

The attack pattern (Table 1) was classified by the game analysis standard of the Japan Water Polo Committee technical development department. A half of field (Figure 1) was divided into four (A~D) by length and five (1~5) by width, using examples from the classified field used by Ratko Rudic. Furthermore, the shot area which was from A1 to D5 was measured with the eye by watching the video.

It took the one-way layout ANOVA after confirming a homoscedasticity by the Levene test to compare the multigroups among the classification. After that, it took the multiple comparison and compared it to the difference among the classifications. The statistical analyses were made with the use of the SPSS 13.0J. The level of statistical significance was set at $p<0.05$.

RESULTS and DISCUSSION

1) Analysis by the attack pattern

In the analysis by the attack pattern, there was the maximum number of 57 shots in "the middle shot in extra-man", and the sub-maximum total of 39 shots in "the middle shot in set offense".

The fastest average shot speed was 74.7 kph of "the penalty shot" (N=14) in the attack pattern. It follows that this shot speed is not less than the speed which was measured by penalty throw in the past research. In addition, the second fastest shot speed was 71.2 kph of "the 5m shot after an ordinary foul" (N=13), the third was 68.7 kph of "the middle shot in set offense" (N=39), and the fourth was 67.1 kph of "the middle shot in extra-man" (N=57). These speeds of shots were all recorded in the standing posture which was the same as "penalty shots" posture. Also, it is characteristic that "the middle shot in set offense" and "the middle shot in extra-man" was taken from several areas, whereas "the 5 m shot after an ordinary foul" was taken from about the same area.

The shot speed in the other attack patterns was slow. For example, the average speed of "the counter attack shot" was 59.4 kph and "the centering shot in extra-man" was 49.6 kph.

It follows from what has been said that the shot motion of those patterns can't build up the speed and the shot speed perhaps wasn't measured correctly because the measuring distance between the shot position and the speed gun was too short.

Thus, it seems that the fast shot speed is more than upper 60s kph and a very fast shot speed is more than 70 kph.

Table 1. Shot Speed Analysis by the Attack Pattern

Attack Pattern	Ave.(kph)	N	%	SD	Max(kph)	Min(kph)
Penalty Shot	74.7	14	8.2	3.42	80.2	68.8
Counter Attack	59.4	17	9.9	12.67	75.9	38.1
Set Offense						
Middle Shot	68.7	39	22.8	8.65	80.6	41.2
5m Shot	71.2	13	7.6	7.19	81.8	57.3
Drive Shot	51.2	6	3.5	9.15	66.5	39.2
Center Forward	51.8	8	4.7	10.27	62.4	32.5
Extra-man Offense						
Middle Shot	67.1	57	33.3	8.64	80.6	45.6
Centering Shot	49.6	13	7.6	10.82	66.9	32.3
Others	72.3	4	2.3	7.14	78.2	61.9
Total	65.1	171	100.0	11.38	81.8	32.3

2) The analysis by the shot area

By analyzing the shot area, there was the maximum number of 64 shots from the 3C area, subsequently to be 2B, 3B and 4B.

The fast speed shots were taken from 2C, 3C and 4C in the vicinity of 5 meter line. The results which were taken by the multiple comparison among the neighbor areas were shown in Figure 1. As a result, a significant difference was not found between right and left in the C area (5~10m), but it was found in B area (2~5m). It seems to be related to that a lot of shots were tapped or pushing a centering ball from 3B area in the vicinity of 2 meter line in the case of extra-man offense.

The fast speed shots were taken from 2B, 3B and 4B area in the vicinity of 5 meter line in the case of “the middle shot in set offense” and “the middle shot in extra-man”.

However, the slow speed shots were often taken from B area in the vicinity of 2 meter line in the case of “the counter attack” and “the centering shot in extra-man”. It was suggested there was a difference between the closest part and the furthest part of the B area from the goal.

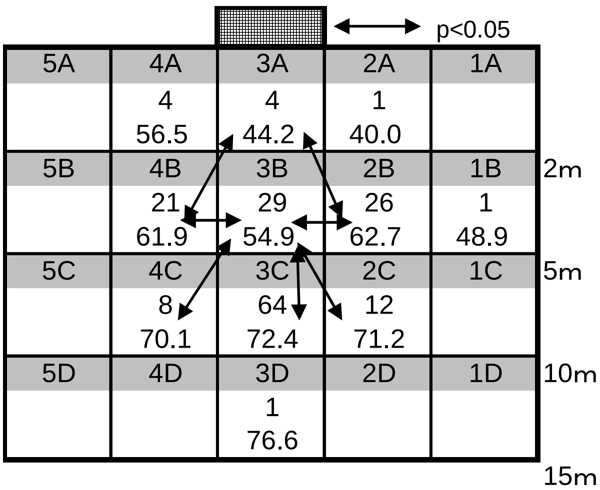


Figure 1. Shot Speed Analysis by the Shot Area

Upper : Shot Area   Middle : Number of Shot   Lower : Shot Speed (kph)

CONCLUSION

It follows from what has been said that a fast speed was often recorded by “the penalty shots” from 3C area, additionally “the middle shots in set offense”, “the 5m shots after ordinary foul” and “the middle shots in extra-man offense” from 2C, 3C and 4C areas. Additionally, a fast speed was recorded by “the middle shots in set offense” and “the middle shots in extra-man offense” from 2B, 3B and 4B near C area.

However, a slow speed is often recorded by “the counter attack shots” and “the centering shots in extra-man” from the B area near the A area. It was suggested that there is a difference in the speed of shots from the B area – depending on where in the B area the shot came from.

Furthermore, the speed of shots from 2B and 4B is slower than it from 2C and 4C. It was suggested that a fast shot speed was recorded near the vertical line to a goal.

REFERENCES

1. Darras NG (1999). The maximum shooting velocity in water polo direct shot and shot with feints of the international level athletes participating in the 10th FINA world cup, In Biomechanics and Medicine in Swimming VIII, Keskinen KL, Komi PV and Hollander AP (Eds.), Gummerus Printing, Jyvaskyla : 185-190.
2. Takagi H (2007). A review of the biomechanical studies of water polo, Jpn J Biomechanics Sports Exerc, 11(2): 68-82.

Visualization of the dolphin kicking wake using 2C-PIV technique

Takahiro Miwa[1], Kazuo Matsuuchi[2], Jun Sakakibara[2], Yuki Muramatsu[2], Takeo Nomura[1]

[1] University of Tsukuba, Graduate School of Comprehensive Human Sciences, Ibaraki, Japan

[2] University of Tsukuba, Graduate School of Systems and Information Engineering, Ibaraki, Japan

The aim of this study was to visualize and to analyze the wake of a swimmer's dolphin kick in a horizontal and a vertical (sagittal) plane using two-component PIV (2C-PIV) technique. PIV allows us to visualize the unsteady flow field instantaneously and to estimate the fluid force. One trained male swimmer was instructed to maintain a swimming position with dolphin kicking in a swimming flume. Unsteady flow fields of dolphin kicking wake in a sagittal and a vertical plane was measured by 2C-PIV. Results of both horizontal and vertical planes showed the pairs of vortices and jet flow between them especially after a downward kicking motion. The direction of the jet flow was mostly oriented to backward. Therefore, it was plausible that the dolphin kicking motion performed in this study generated a propulsive force by generating the vortex pair and the jet flow as a reaction force.

Key Words: *PIV, dolphin kick, unsteady flow, vortex ring, jet-propulsion*

INTRODUCTION

In competitive swimming using four modern styles, the dolphin kicking motion or butterfly kick is used after the start and turn. The dolphin kicking motion, which resembles the propelling locomotion of the dolphins, produces a high propulsive force by the momentum induced due to the up and down motion of the feet. In addition, the underwater undulation swimming phase after the start and turn presented an advantage of less wave drag (2). Therefore, effective dolphin kicking is very important to improve swimming performance in competitive swimming (1, 2, 3). Ungerechts et al. (7) emphasizes the reverse action of the kick, using a whip-like action as much as possible to propel the swimmer more effectively. Furthermore, Arellano et al. (2) visualized the flow with bubbles in dolphin kicking wake and reported that the efficient undulatory underwater swimmer created a large vortex at the end of the downward kick and a small vortex at the end of the upward kick to obtain a strong propulsive force.

The recent researches about the propulsive mechanism of natural creatures, like fishes or insects, in the unsteady flow fields revealed that those creatures generated the propelling force by creating the vortices and by using unsteady fluid force (4). Although it is suggested that the human beings also can swim effectively by means of unsteady fluid force, there are few researches in human swimming related to the unsteady flow mechanism (5).

The aim of present study was to visualize and analyse the wake of a swimmer's dolphin kick in a horizontal and a vertical (sagittal) plane to obtain the knowledge of propulsive mechanism of dolphin kick using two-component Particle Image Velocimetry (2C-PIV). The algorithm for detecting the particle velocity is same as that of Sakakibara et al. (6).

METHOD

1. Subject and Trial

One trained male swimmer participated in this study and was asked to give informed consent. The experiment was executed in a swimming flume (4.6 × 2.0 × 1.5 m; Igarashi Industrial Inc., Japan). The swimmer was instructed to remain in the same place relative to the oncoming flow with dolphin kicking. Trials were executed with the flume flow speed of 1.2 m/s.

2. PIV set-up

A schematic view of PIV system is shown in Figure 1. The measurement region size was at most 0.50 × 0.50 m (0.25 m^2). Polymer particles were used as a tracer to determine the flow velocity. The laser light (Solo PIV 120; New Wave Research, Inc., USA) was spread as a sheet and directed horizontally and vertically to the swimming flume to illuminate the tracer particles. Two hundreds sequential images of illuminated particles at the flow field of dolphin kicking wake were captured using the CCD camera, and the images were stored in the host memory of the PC via the image grabber (Coreco Imaging Inc., Billerica, USA). The timing of image capturing and laser exposure were synchronised with a pulse generator (Model 9314; Quantum Composers Inc., Bozeman, MT, USA). Particle velocity and vorticity, which indicates the strength and the rotational direction of the vortices, were calculated by sequential two particle images (5).

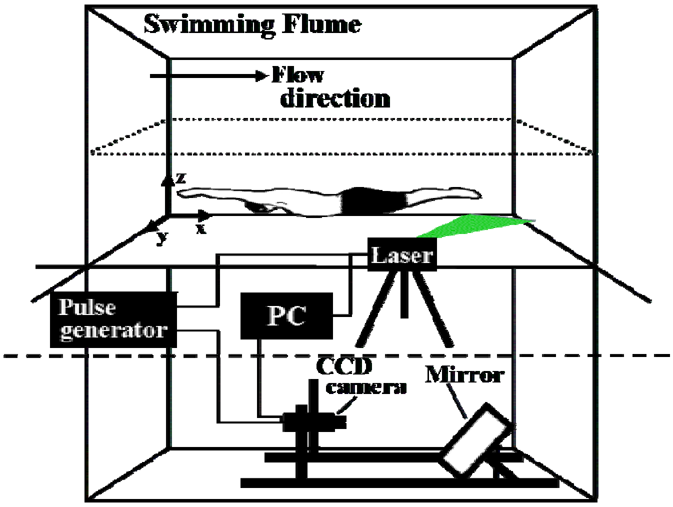


Figure1. Schematic view of a 2C-PIV setup with the swimming flume (horizontal plane).

RESULT and DISCUSSION

1. Visualization result of horizontal (x-y) plane.

Time sequential aspects of the unsteady flow fields were obtained at the horizontal plane in the dolphin kicking wake (Fig.2). The size of white rectangle in Fig.2-a is identical to that of particle vector and vorticity result of Fig.2-b and Fig.2-c. The mean velocity was subtracted from the calculated raw vector data to detect the flow field details, thereby clarifying the effect of vorticity. Because of the subtraction, dots correspond to the uniform flow and vectors express the velocity deviation from the uniform flow (1.2 m/s). Direction of the uniform flow is from left to right. The coloured distribution in the figure and the legend indicates the vorticity. Red and blue colour indicates anticlockwise and clockwise vortex rotation, respectively. The area filled with white colour indicates the foot position in the measurement plane.

Almost no changes were observed before the feet passing through the horizontal laser sheet during downward kicking (Fig.2-b: t = 0 ms). On the other hand, the pair of vortices was observed after the feet passing through the laser sheet (Fig.2-c: t = 67 ms). It was confirmed that the pair of vortices was moving backward over time along with the uniform flow. It was also confirmed that the jet flow between the vortex pair, directed to the same direction as the uniform flow. Aquatic animals like fishes generate the jet flow in the wake and obtain the propulsive force using the jet flow as a reaction force (4, 6). According to the direction of jet flow in human dolphin kicking wake, it was suggested that human also generates the propulsive force by creating the vortices in

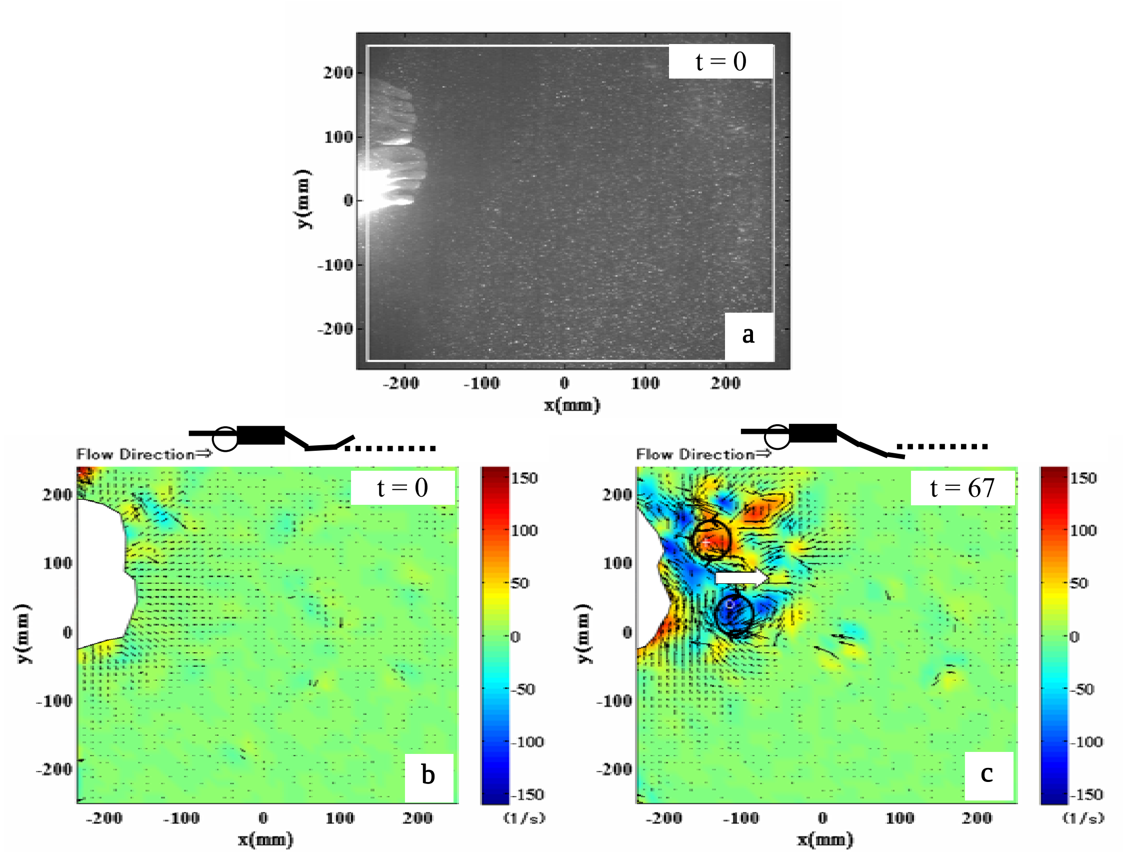


Figure 2. Exemplary particle image of downward dolphin kicking motion before passing through the horizontal laser sheet (a: t = 0), the vector-vorticity result corresponding to inside of white rectangle of the particle image (b: t = 0) and the result of after passing through the laser light (c: t= 67 ms)

the wake with their feet during dolphin kicking. It was also confirmed that there were vortex pairs and the jet flow during upward kicking. Therefore, the upward kicking also seems to contribute to the thrust.

2. Visualization result of vertical (x-z) plane.

Figure 3 shows the time sequential particle vector and vorticity aspects of unsteady flow fields in a vertical (sagittal) plane of dolphin kicking wake. The left column in the figure indicates the down kick phase and the right column indicates the upward kick phase. The top panel of left column shows a particle image at t = 0, and it corresponds to the velocity vector and vorticity result at t = 0 (second top in the left column). The interval of each result is 67 ms. The main flow direction is along the x-axis. White coloured shape in the figures represent the feet and the black indicate the shadow in the laser sheet interrupted by the feet. Therefore, the displacements of the tracer particles are not detected in this area.

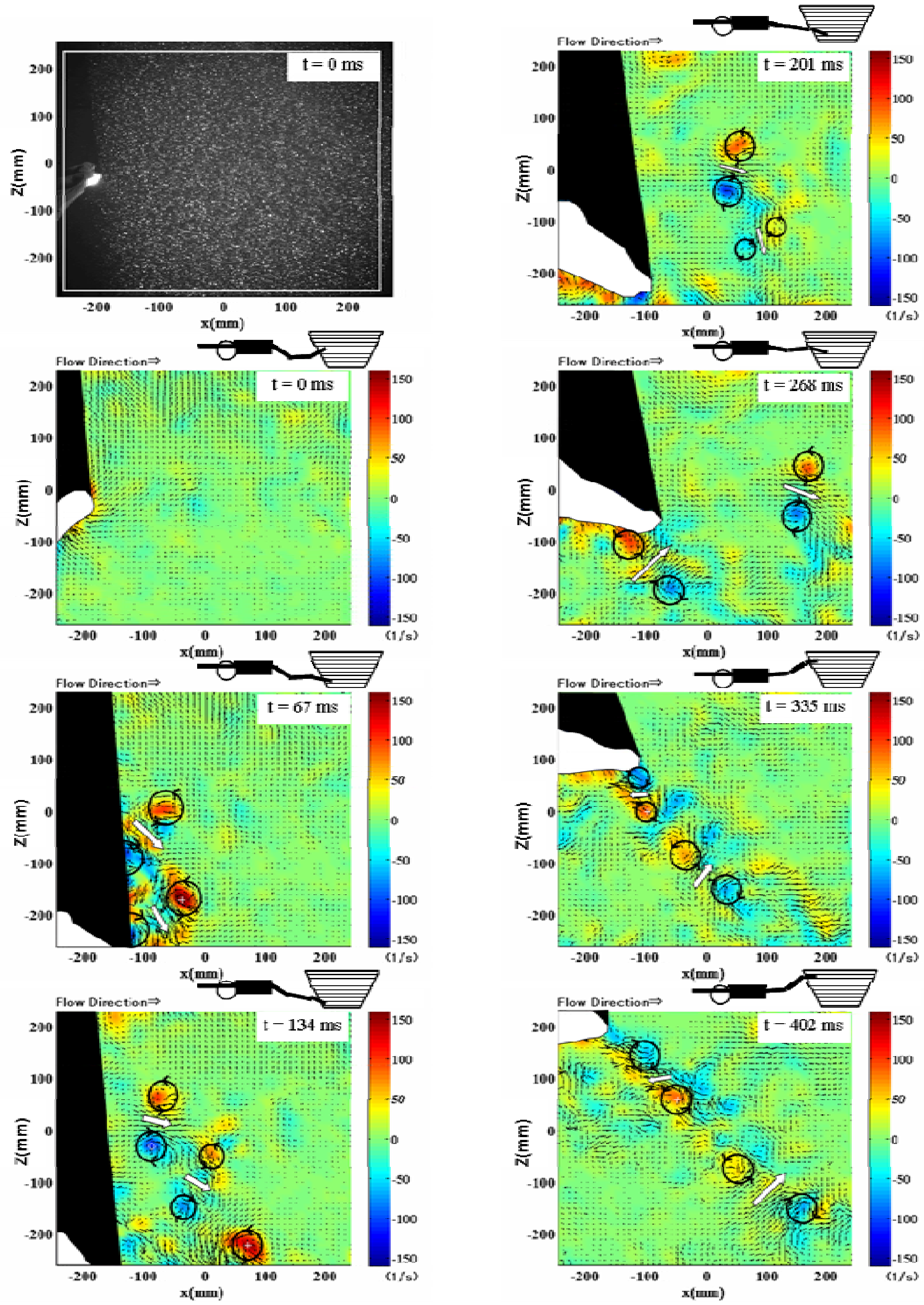


Figure 3. Examples of time sequential velocity fields during the downward (left column) and upward (right column) dolphin kicking motion in a given moment. The interval of each result is 67 ms.

There are some of vortex pairs and jet flow which direction is along the x-axis or lower right during downward kicking (Fig.3 left column). The x-axis component of the jet flow seems to contribute to the thrust. The jet flow directed to upper right was generated during the upward kicking phase (Fig.3 right column) and the x-axis component of this jet flow contribute to the thrust as well as downward kicking phase. On the other hand, the jet flow confirmed at the results of t = 335 and t = 402 directed to the opposite to the main flow direction. It was suggested that the final phase of the upward kicking seemed to be a kind of brake rather than contributing to thrust forward.

In conclusion, the present study visualized and analysed the wake of the swimmer's dolphin kick using 2C-PIV. It was suggested that the dolphin kicking swimmer in this study generated the propulsive force by using induced vortex pairs and jet flow as a reaction force.

ACKNOWLEDGMENTS

This work was supported by a Grant-in-Aid for Scientific Research ((B) (2)16300202)) and a partly ((B) (2)15300216)) of the Japan Society for the Promotion of Science, Japan.

REFERENCIES

1. Arellano, R. (1999). Vortices and propulsion. In Swimming: Proceedings of the XVII International Symposium on Biomechanics in Sports, (edited by Ross Sanders & Joram Linsten), pp. 53–65. Perth, Western Australia: School of Biomedical and Sports Science.
2. Arellano, R., Pardillo, S., Gavilan, S., (2002), Underwater undulatory swiming: kinematic characteristics, vortex generation and application during the start, turn and swimming strokes, Universidad de Granada: ISBS 2002 Proceedings.
3. Colwin, C. (2002). Breakthrough Swimming. Champaign: Human Kinetics
4. Dickinson, M.H., Farley, C.T., Full, R.J., Koehl, M.A.R., Kram, R. & Lehman, S. (2000). How animals move: An integrative view. Science, 288, 100–106.
5. Toussaint HM, Van den Berg C, Beek WJ (2002). "Pumped-up propulsion" during front crawl swimming. Medicine and Science in Sports and Exercise, 34, 314-319.
6. Sakakibara, J., Nakagawa, M., Yoshida, M (2004). Stereo-PIV Study of Flow around a Maneuvering Fish, Experiments in Fluids, 36, pp.282-293
7. Ungerechts BE, Daly D, Zhu JP (1998). What dolphins tell us about hydrodynamics. Journal of Swimming Research 13, 1-7.
8. Ungerechts BE, Persyn U, Colman V (1999). The application of vortex flow formation to self-propulsion in water. Biomechanics and Medicine in Swimming VIII. Gummerus Printing, Jyväskylä, 95-100.

Development of a Synchronized System of PIV and Motion Analysis, and Its Application to a Front Crawl Swimmer

Yuki MURAMATSU[1], Kazuo MATSUUCHI[1], Takeo NOMURA[2], Jun SAKAKIBARA[1], Takahiro MIWA[2]

[1] University of Tsukuba, Faculty of Systems and Information Engineering, Japan

[2] University of Tsukuba, Faculty of Comprehensive Human Science, Japan

Flow fields around a swimmer are extremely unsteady. Top swimmers are supposed to swim using unsteady flow force effectively. PIV can visualize the unsteady flow field around swimmer's hand. A motion analysis can analyze the unsteady motion of swimmer quantitatively. Our main aim is to construct a synchronized system of the two methods, and to apply it to a front crawl swimmer, in order to clarify the relationship between swimmer's hand motion and the vortex generated by hand. To combine two methods, we illuminated swimmer's hand with the red lights, and separated the lights by passing it through Laser Line Band Pass Filter and Red Band Pass Filter for PIV and for High-speed camera, respectively. To synchronize two types of images, we utilized the first shutter timing of a pulse generator and set the shutter period to 72ms in PIV and 8ms in a motion analysis.

Key words: *PIV, Motion Analysis, Front Crawl, unsteady flow, vortex, circulation*

INTRODUCTION

Schleihauf (1) evaluated a force exerted on a hand model in swimming based on the quasi-steady theory. However, swimmer's motion cannot be evaluated quantitatively by the quasi-steady analysis, although the flow field has extremely unsteady characteristics.

Unsteady lift force is generally greater than the steady one. Top swimmers are supposed to swim using effectively the unsteady flow force. Counsilman (2) found S-shaped pull as a result of the motion analysis for top swimmers and concluded that such a pull motion is essential in crawl swimming. We paid our attention to a phase turning from In-sweep to Out-sweep of S-shaped pull. Fig.1 shows a palm trace in a horizontal plane. The flow direction was in the positive X-direction. The orientation of the circulation around a swimmer's hand reversed in the two places denoted by (α) and (β) in Fig.1 (a). In these places, a hand gained larger propulsion by shedding a strong and large vortex according to the conservation law of circulation.

A motion analysis can evaluate the unsteady motion of swimmers quantitatively on digitizing the motion of the swimmer. Fig.1 (b) shows the definition of the pitch angle used in our motion analysis. In the figure, $\vec{Vr}$ was the palm velocity relative to water. We defined the pitch angle θ as an angle between $\vec{Vr}$ and the flow direction. In In-sweep θ was negative and the orientation of the circulation was clockwise, while in Out-sweep θ was positive and the orientation of the circulation was counterclockwise.

In addition, Particle Image Velocimetry (PIV) is used to visualize the unsteady flow field around a swimmer (3, 4). With this method, vortex motion around the hand can be evaluated quantitatively. We referred to the vortex rotating clockwise as negative and to the one rotating counterclockwise as positive.

In the traditional study, however, PIV and a motion analysis were carried out individually. The aim of this study was to construct a synchronized system of two methods, and to apply the system to a front crawl swimmer, in order to clarify the relationship between swimmer's hand motion and the behavior of vortices generated by the motion.

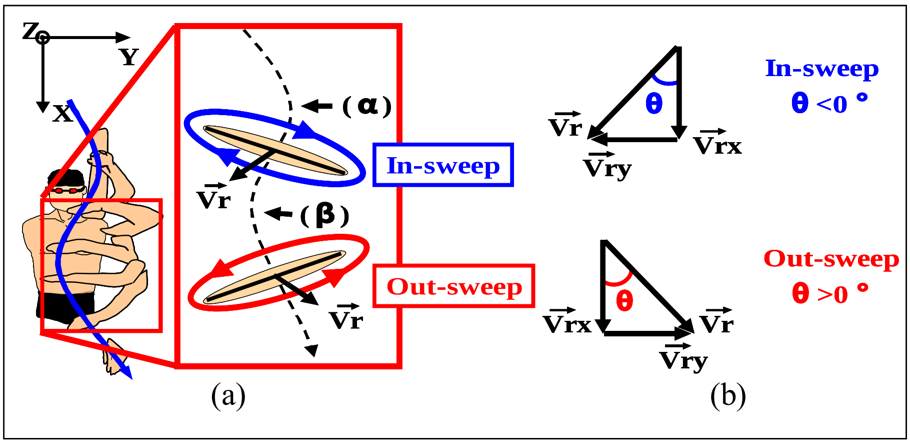


Figure 1. (a) :The orientation of the circulation around a swimmer's hand reverses from (α) to (β). (b) :The definition of pitch angle θ.

METHODS

PIV (in X-Y plane)

PIV system measures the flow velocity from the movement of tracer particles irradiated with YAG laser sheet. The maximum frequency of our YAG laser was 15Hz. The laser sheet was set in the horizontal plane located at a depth of 0.6m below the water surface. The image of the tracer particles was reflected by a mirror and captured by a CCD camera set at the bottom of the flume and the image was then transferred to a computer.

Motion analysis

In order to determine the three dimensional coordinates of the palm, we adopted Direct Linear Transformation method, which had been popularly adopted in the field of biomechanics. Two synchronous high-speed cameras were placed at the side (camera 1) and at the bottom (camera 2) of the flume. The camera 2 was used in combination with a mirror inclined at an angle of 45deg. The thumb, the middle finger and the little finger were digitized by a video motion analysis system Frame-DIAS 2 version 3, so that three dimensional coordinates were calculated. The velocity of the palm was defined as the velocity at the middle point of the segment between the thumb and the little finger.

Synchronization

Generally, PIV system was carried out in the dark because it measured the movement of tracer particles irradiated by YAG laser sheet, instead of the flow field itself. On the other hand, a motion analysis was carried out in the light. To combine these methods, we illuminated a swimmer's hand with the red lights, and separated the light by passing it through Laser Line Band Pass Filter and Red Band Pass Filter for PIV and for High-speed camera, respectively. We synchronized two types of images with the first shutter timing of a pulse generator, setting the shutter period to 72ms in PIV and 8ms in a motion analysis. Then, by applying the synchronized system to a swimmer, we could get images synchronized by 72ms. Fig.2 shows the experimental configuration of our synchronized system.

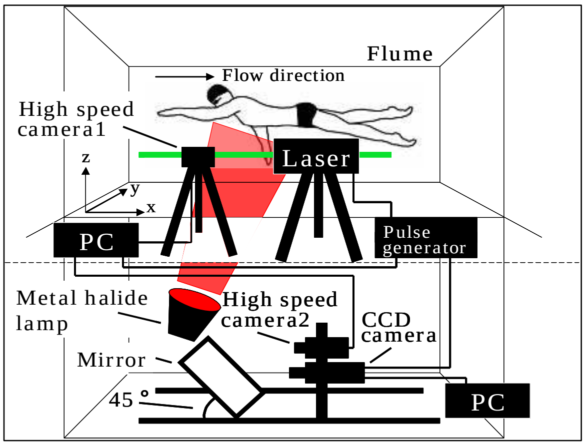
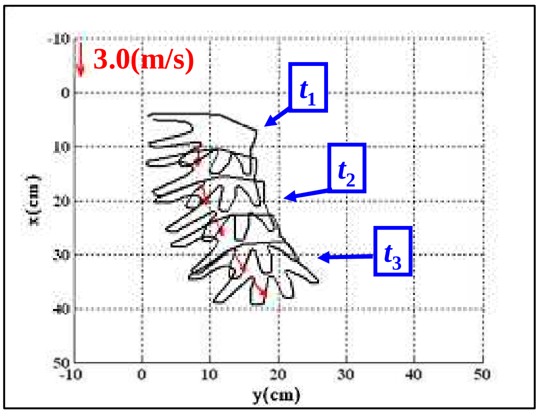


Figure 2. The experimental configuration of the synchronized system.

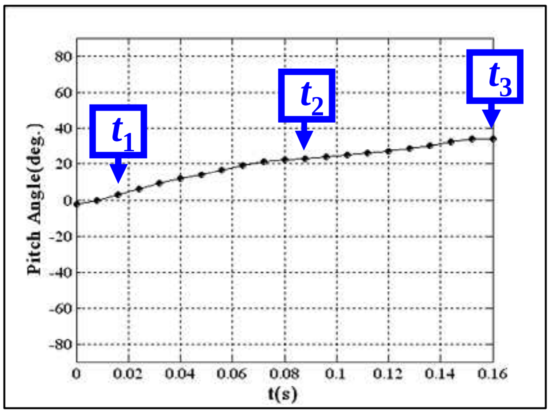
RESULTS AND DISCUSSION

Fig.3 (a) shows the palm trajectory from In-sweep to Out-sweep. This picture was viewed from the bottom of the flume. The flow direction was in the positive X-direction. The red arrows show the palm velocity vectors at each moment. From the direction of the velocity vectors, it was suggested that the subject reverses the direction of the palm. Then, Fig.3 (b) shows the change of pitch angle. Time t_1, t_2 and t_3 are the sequential ones when images synchronized by 72ms were obtained. At $t = 0$, θ was still negative. About 8ms later, θ became $0°$ and consequently the subject reversed the orientation of the circulation around the hand at this instant. Thereafter, as the time passed, the pitch angle increased.

Fig.4 shows the distributions of velocity vectors and vorticities at t_1, t_2 and t_3. The mean flow velocity was subtracted from the X-component of velocity vectors to clarify the vortex behavior itself. The color scale on the right column of these figures denoted the vorticity measured in 1/s. A counterclockwise vortex was denoted by red, and a clockwise vortex by blue. White ovals denoted the position of the palm at each time. Error vectors in the shade of the hand were removed by white rectangles. At t_1, the orientation of the circulation had just reversed. From Fig.3 and Fig.4, no vortex seemed to be emitted yet at this time. Thereafter, at t_2 a new vortex was generated at the wake on the back of the palm. However, the blue-colored counterclockwise vortex was not emitted yet. The vortex seemed to be a free one generated by changing the orientation of the circulation. At t_3, the vortex was already emitted, and downwards velocity vectors were induced between the emitted vortex and the circulation around the palm.

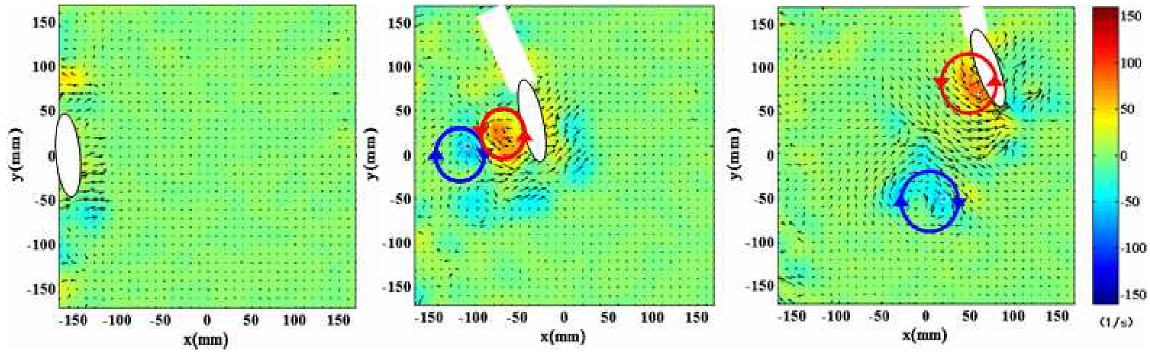


(a)



(b)

Figure 3. (a) :Hand trace viewed from the bottom of the flume. (b) :Change of pitch angle.



(a) t_1 (b) t_2 (c) t_3

Figure 4. Distributions of velocity vectors and vorticities

CONCLUSION

To clarify the propelling mechanism of swimming, we could develop a PIV system synchronized with a motion analysis, and succeeded in getting images of flow field synchronized with hand positions at every 72ms. Applying our synchronized system to a swimmer, we could derive the time connection between swimmer's hand motion and the flow field in the transition phase from the point of view of vortex behavior.

REFERENCES

1. Schleihauf RE (1979). A hydrodynamic analysis of swimming propulsion. Swimming III. 70-109.
2. Counsilman JE (1971). The application of Bernoulli's principle to human propulsion in water. Swimming I. 59-71.
3. Matsuuchi K, Miwa T, Nomura T, Sakakibara J, Shintani H, Ungerechts BE (2004). Unsteady flow measurement around a human hand in swimming using PIV. 9th Annual Congress of the ECSS. CDROM.
4. Yamada K, Matsuuchi K, Nomura T, Sakakibara J, Shintani H, Miwa T (2006). Motion analysis of front crawl swimmer's hands and the visualization of flow fields using PIV. Biomechanics and Medicine in Swimming X. 111-113.

Unsteady effect on the propulsive force in the arm pull of crawl swimming

Kazuo Matsuuchi[1]

[1] University of Tsukuba, Faculty of Systems and Information Engineering, Japan

Generation of propulsive force in swimming was investigated. In knowing the mechanism of the generation information on the complex hand motion and the unsteady flow are important. The conventional quasi-steady theory cannot give the correct understandings on the generating mechanism of the propulsive force. The role of unsteadiness is critical in the generation of momentum and therefore in the force production. Two high-speed cameras determined the hand trace including the time variation of the geometry of a palm. It was found that the reduced frequency for the variation is too high to neglect the unsteadiness and the hand speed of the elite swimmer is not necessarily fast, which cannot be explained by the quasi-steady theory.

Key words: *Crawl Swimming, Propulsive Force, Unsteady Flow*

INTRODUCTION

The quasi-steady theory, which is based on the assumption of the steady flow, has been only a theoretical basis to evaluate the propulsive force in swimming. Confining ourselves to the force generated by a hand motion in crawl swimming, we investigate the validity of the theory. The flow around a hand arising from its motion is known to be extremely unsteady. Many researchers such as Counsilman(1) have investigated the hand trace. According to Counsilman a sideways orientation of stroke movement is important and hence the lift force rather than drag force plays an important role in the generation. The principal guide for explanation is the well-known Bernouille's theorem in fluid mechanics. Schleihauf (2) made an experiment using a hand model in a steady situation and asserted the Counsilman's idea. However, since most of recent top swimmers swim with less sideway movement, some researchers doubted the importance of lift force as a propulsive one (see, for example, Maglischo (3)).

The basis mentioned above is the dynamics of an arm or a hand around which the fluid is supposed to be steady. A few recipient researchers were able to see the flow using the bubbles entrained naturally or artificial bubbles for visualization (4)(5). The flow field around a hand was also visualized quantitatively and systematically by use of the Particle Image Velocimetry (PIV) (6). They pointed out the importance of unsteady behavior of vortices generated by the movement of hand or arm.

In the present paper, we will discuss the importance of unsteady characteristics of flow arising from the complex arm movement and also mention about some defects of the quasi-steady theory for the estimation of propulsive forces.

QUASI-STEADY THEORY AND USTEADY CHARACTERITICS

Hand trace and hand speed

First, we show a hand trace in crawl swimming. In Fig.1 the trace viewed from below is drawn schematically. There are two transition phases; one is the transition from the catch to in-sweep and the other one from in-sweep to out-sweep. We call the former Trans 1 and the latter Trans 2.

Next we discuss the effect of hand speed on the propulsive force in swimming. The force exerted on an object under steady flow whose velocity is U is estimated using the following formula,

$$D = c_D \frac{1}{2} \rho U^2 S , \quad L = c_L \frac{1}{2} \rho U^2 S , \qquad (1)$$

where D and L are drag and lift force, respectively, ρ the density of fluid, and S usually the projected area of the object. In the formula the most effective quantity that increases the force intensively is the stream velocity D, because the force is proportional to the square of it.

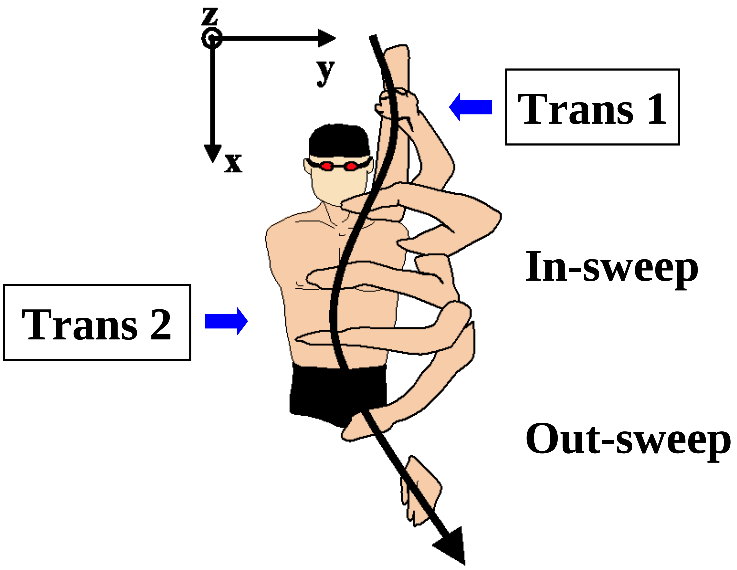


Fig.1 Two transition phases in the S-shaped pull.

To know the actual hand speed of swimmers, the speed of three swimmers was measured. In Fig.2 the speed in the in-sweep is drawn for two swimmers; one is an elite swimmer, Subject 1, and the other a beginner, Subject 3. It is clear that the elite swimmer does not move the hand so fast, while the beginner pulls back the arm faster. The reason cannot be explained by the quasi-steady theory. The fast swimmer does not draw back the hand but the strong force is exerted, and as a result the trunk could move forward.

The hand speed obtained by Schleihauf et al. (7) is also depicted in Fig.3. At the instant (a) the hand is at the start of in-sweep, at (b) the transition phase from in-sweep to out-sweep.

The end of out-sweep is denoted by (c). The slowest speed occurs at the instant i=17 and the corresponding speed is 1.67 m/s. On the other hand the fastest velocity is 3.39 m/s between i=17 and 18. According to the quasi-steady theory the swimmer received the strongest force from water at this instant. However, it is plausible that at that period the speed of trunk relative to water becomes slow because the hand speed relative to water is fast.

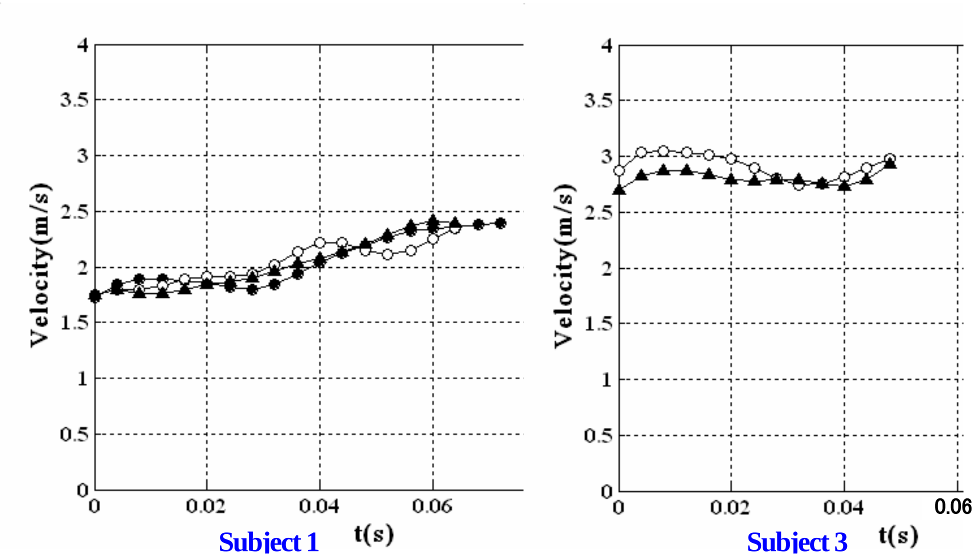


Fig.2 Hand speed of two subjects with different careers at the transition phase 2, Trans 2. Subject 1 is an elite swimmer in Japan and Subject 3 is one with no swimming career. For Subject 1 and Subject 3, three and two strokes were drawn, respectively.

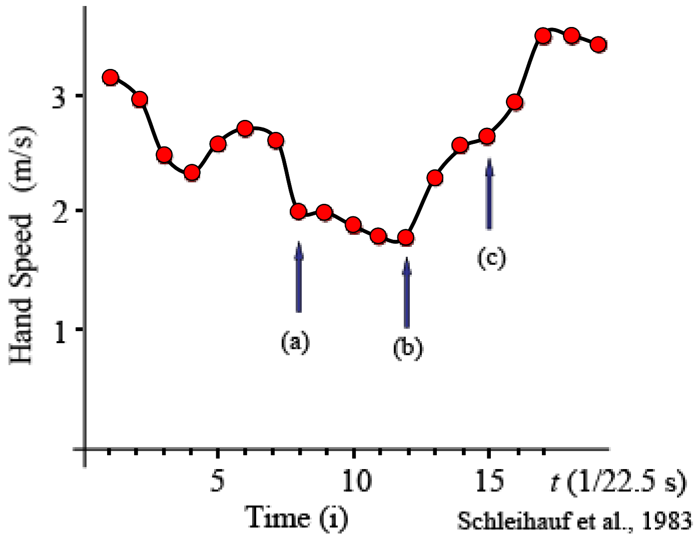


Fig.3 Hand speed in a whole stroke (adapted from the data by Schleihauf et al. (7).

Reduced frequency

Swimmers change not only the hand trace intricately from in-sweep to out-sweep or vice versa but also alter an angle of palm relative to water. We call an angle of flow direction relative to palm the "pitch angle" (see Ref.(9)). The time variation of the angle is shown in Fig.4 in two transition phases for the elite swimmer, Subject 1. It is easy to see that the change is very rapid. The period is estimated roughly as 0.1 s. It is known that a measure of unsteadiness is the reduced frequency k defined by $k = \pi f c / U$. In the present problem f is the frequency of pitch angle, c the chord of palm as a hydrofoil, and U the flow velocity relative to the palm. Setting =1.6 m/s and =0.14 m, the reduced frequency becomes k =2.7 for f =0.1 s. This value is too large to suppose the flow to be steady (10).

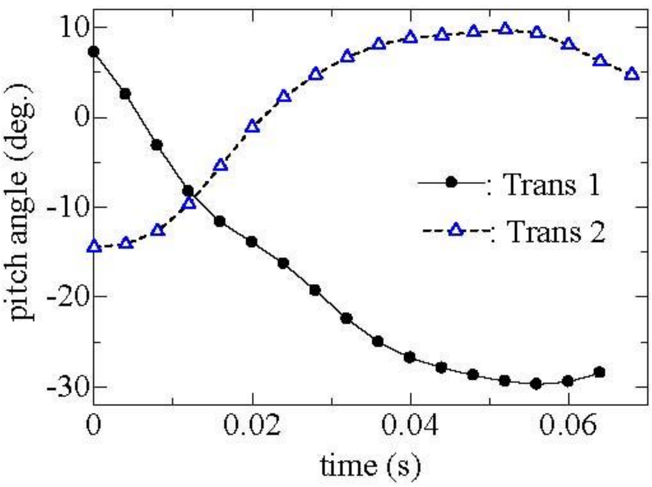


Fig.4 Time variation of pitch angle at two transition phases.

CONCLUSION

High speed stroke does not necessarily mean the generation of large propulsive force. Unsteady mechanism of the generation of force is important in the evaluation of propulsive force in swimming, because the reduced frequency is very high and thus the fluid motion becomes unsteady.

REFERENCES

1. Counsilman J (1969). The role of sculling movements in the arm pull, Swimming World, 10-12, 6,7,43.

2. Schleihauf RE (1974), A biomechanical analysis of freestyle}, Swimming Technique, 11-3, 89-96.

3. Maglischo EW (2003), Swimming Fastest, Human Kinetics, (2003), Chap.1.

4. Arellano R (1999), Vortices and propulsion, Proc. of the XVII International Symposium on Biomechanics, 53-65.

5. Colwin C (2002), Breakthrough Swimming, Human Kinetics, (2002), Chap.5.

6. Matsuuchi K, Miwa T, Nomura T, Sakakibara J, Shintani H, Ungerechts BE (2004). Unsteady flow measurement around a human hand in swimming using PIV. Proc.9th Annual Congress of ECSS, CDROM.

7. Schleihauf RE, Gray L, DeRose J (1983), Three-dimensional analysis of hand propulsion in the sprint front crawl, Biomechanics and Medicine in Swimming, Human Kinetich, (1983), 173-183.

8. Yamada K, Matsuuchi K, Nomura T, Sakakibara J, Shintani H, Miwa T (2006).
Motion analysis of front crawl swimmer's hands and the visualization of flow fields using PIV. Biomechanics and Medicine in Swimming X. 111-113.

9. Yamada K (2007), Hand motion and visualization of flow field by PIV around a hand in crawl swimmers, Master Thesis of Doctor Program of Systems and Information Engineering, Univ. Tsukuba, (in Japanese).

10. Azuma A (1993), Fluid Mechanics, Asakura Pub., pp.20-21, (in Japanese).

Musculoskeletal Simulation to Estimate Muscle Activity in Swimming

Motomu Nakashima[1] and Yugo Motegi[2]

[1]Tokyo Institute of Technology, Department of Mechanical and Environmental Informatics, Japan
[2]Nissan Motor Co., Ltd., Japan

The objectives of this study were to conduct the musculoskeletal simulation for the breast, back, and butterfly strokes using a musculoskeletal simulator which was recently developed by the authors, and to examine the validity of the simulator. Based on educational movies of an elite swimmer, standard swimming motions for the three strokes were constructed and input to the simulator. The body geometry of averaged Japanese male of 20-30 years old was also input. Many reasonable tendencies were obtained in the simulation results. These results suggested that the musculoskeletal simulation for swimming will be a powerful tool to assess the swimming motion.

Key words: Swimming, Biomechanics, Musculoskeletal simulation, SWUM

INTRODUCTION

The musculoskeletal simulation is getting popular in various fields of biomechanics. In the musculoskeletal simulation, the muscles in the human body are modeled as many wires, and the muscle activity (muscle force) is estimated solving an optimization problem to determine the muscle force distribution. By the musculoskeletal simulation, many useful information for training, coaching, rehabilitation, and so on, can be obtained. However, there have been no studies of the musculoskeletal simulation for swimming since the external force acting on the whole body as the input to the musculoskeletal simulation was difficult to measure or estimate. The authors have recently developed a simulation model SWUM (SWimming hUman Model) in order to analyze the mechanics of swimming [6,7]. The analysis of the crawl stroke [3,6] and the other three strokes [4] have been already conducted, and their results indicate a certain validity of SWUM. Since the unsteady fluid force acting on each part of the whole body can be estimated by SWUM, the authors recently developed a musculoskeletal simulator for swimming by integrating SWUM and a commercial musculoskeletal analysis software [5]. In this preceding study, the musculoskeletal simulation of the crawl stroke was conducted using the simulator, and the qualitative validity of the simulator was verified by comparing the simulation results with EMG results. The objectives of this study were to conduct the musculoskeletal simulation for the breast, back, and butterfly strokes, and to examine the further validity of the simulator.

METHODS

Firstly, the simulation model SWUM was designed to solve the six degrees-of-freedom absolute movement of the whole human body as one rigid body, using the inputs of the human body geometry and relative joint motion. Therefore, the swimming speed, roll, pitch and yaw motions, propulsive efficiency, joint torques and so on are computed as the output data. As the external forces acting on the whole body, unsteady fluid force which includes buoyancy and gravitational force are taken into account. The unsteady fluid force, which consists of inertial force due to added mass of fluid, normal and tangential drag forces and buoyancy, is assumed to be computable, without solving the flow, from the local position, velocity, acceleration, direction, angular velocity, and angular acceleration at each part of the human body at each time step. For the musculoskeletal analysis, a commercial software "AnyBody Modeling System" [1] (AnyBody Technology, Denmark) was employed. The full-body model with 458 muscles was used for the present study. And SWUM and AnyBody were connected seamlessly by a free software "Swumsuit", which was developed by the authors [5,7].

Based on educational movies of an elite swimmer, standard swimming motions for the three strokes were constructed and input to the simulator. The body geometry of averaged Japanese male of 20-30 years old was also input.

RESULTS AND DISCUSSION

Breaststroke

The simulation results of the breaststroke are shown in Figs.1 and 2. Figure 1 represents

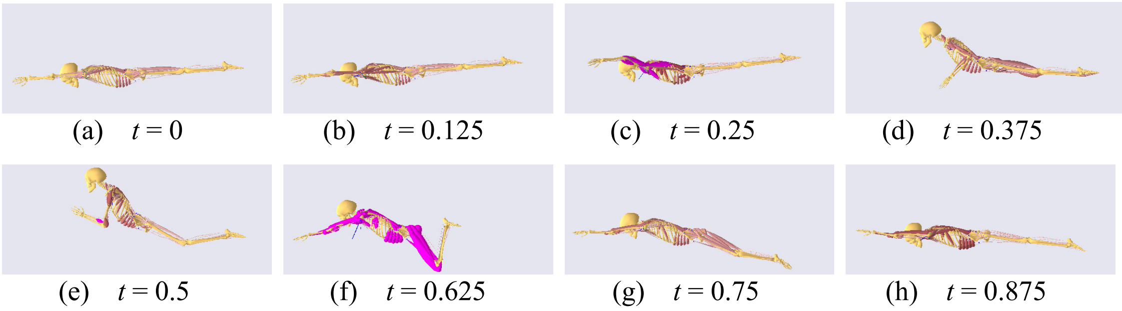


Figure 1. Swimming motion for one stroke cycle (Breaststroke).

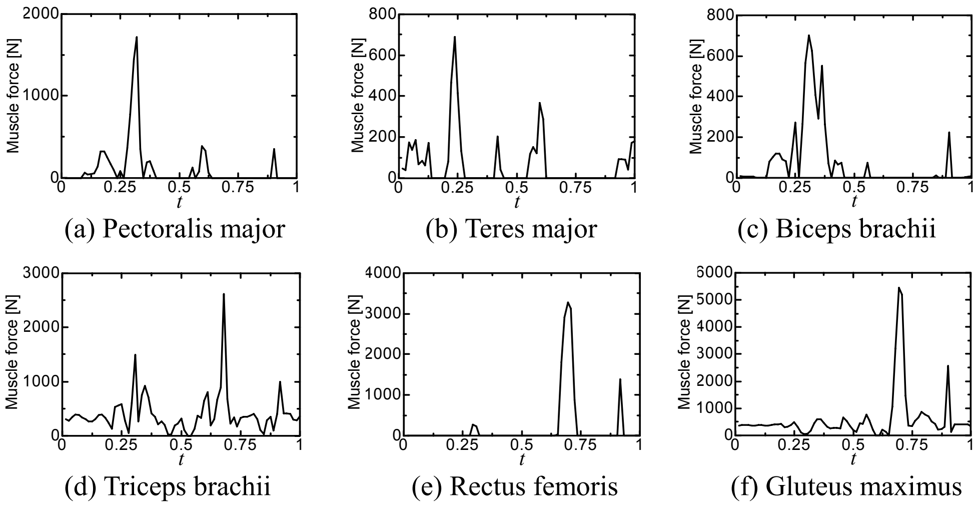
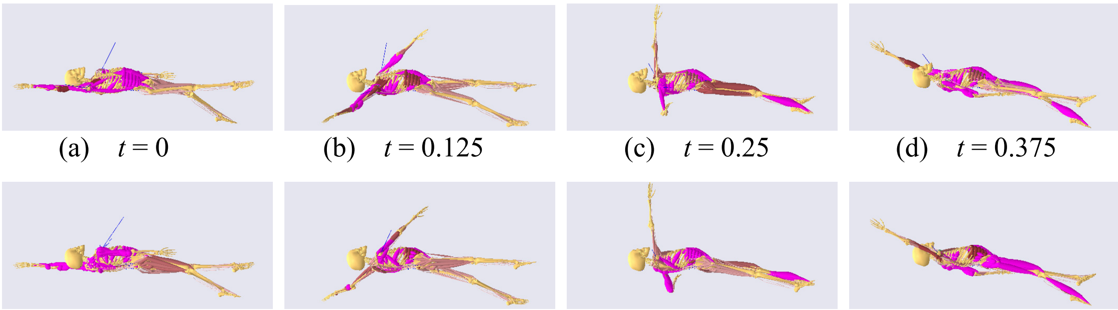


Figure 2. Muscle force for left side of the body (Breaststroke).

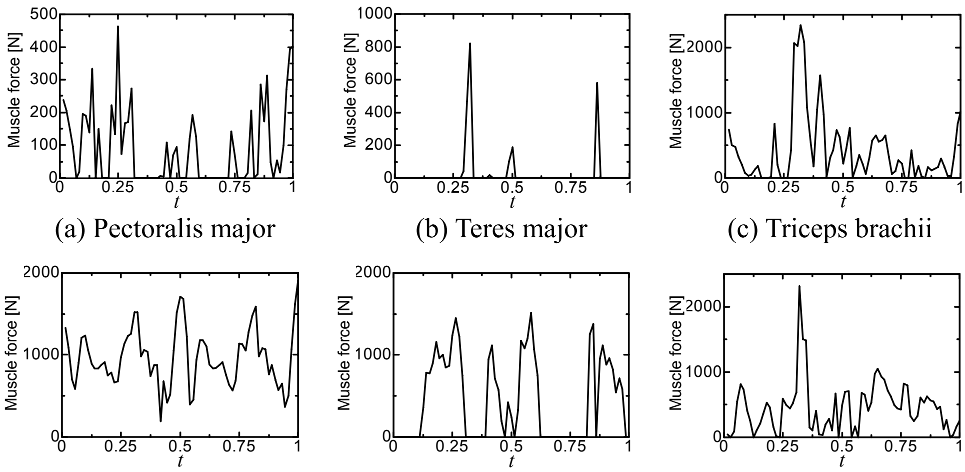
the swimming motion for one stroke cycle (time is nondimensional). The pink and thick wires represent muscles with large muscle force. Figure 2 shows the muscle force for the six muscles. With respect to the upper limb, it is found that pectoralis major, teres major, and biceps brachii (elbow flexor), becomes significantly active during the 'pull' motion ($t = 0.25$~0.375). This tendency corresponds to EMG results by Ikai et al [2]. It is also found that triceps brachii becomes active at the kick motion ($t = 0.625$~0.75). This activation is accompanied by the recovery motion, in which the swimmer is stretching the upper limbs forward. Thus, the reason for this activation may be that the upper limbs are exposed to the large fluid force due to the acceleration by the kick. With respect to the lower limb, it is found that rectus femoris and gluteus maximus become significantly active corresponding to the extension of hip and knee joints during the kick ($t = 0.625$~0.75). This tendency also corresponds to the EMG results by Ikai et al [2].



(a) $t = 0$ (b) $t = 0.125$ (c) $t = 0.25$ (d) $t = 0.375$

(e) $t = 0.5$ (f) $t = 0.625$ (g) $t = 0.75$ (h) $t = 0.875$

Figure 3. Swimming motion for one stroke cycle (Backstroke).



(a) Pectoralis major (b) Teres major (c) Triceps brachii

(d) Rectus abdominis (e) Rectus femoris (f) Gluteus maximus

Figure 4. Muscle force for right side of the body (Backstroke).

Backstroke

The simulation results of the backstroke are shown in Figs.3 and 4. With respect to the upper limb, it is found that pectoralis major becomes active during the pull motion ($t = 0$~0.25), and that triceps brachii, teres major, and pectoralis major become active during the push motion ($t = 0.25$~0.375). Pectoralis major also seems to be active during the recovery motion ($t = 0.5$~0.875). The reason for this may be that the swimmer has to maintain the upper limb above the water against the gravity during the recovery motion. With respect to the lower limb, it is found that the muscle force of rectus femoris has large three peaks corresponding to the flutter kick. In the meantime, gluteus maximus does not exhibit obvious peak except one during the push motion ($t = 0.25$~0.375). With respect to the muscle in the trunk, rectus abdominis exhibits the continuous activation all the stroke cycle. This activation may prevent the lower limbs from sinking due to the

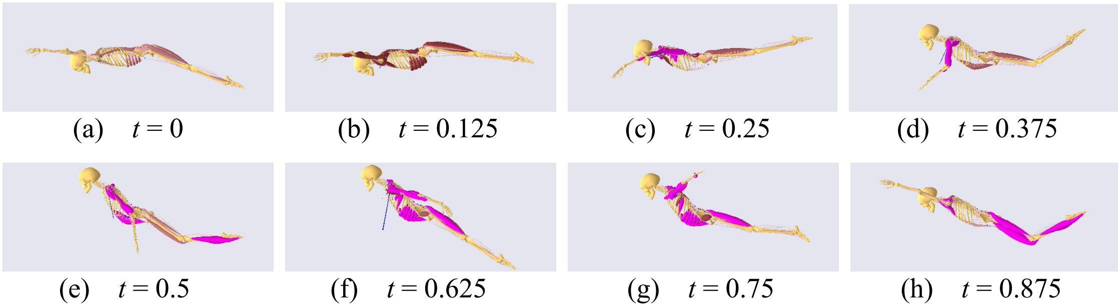


Figure 5. Swimming motion for one stroke cycle (Butterfly stroke).

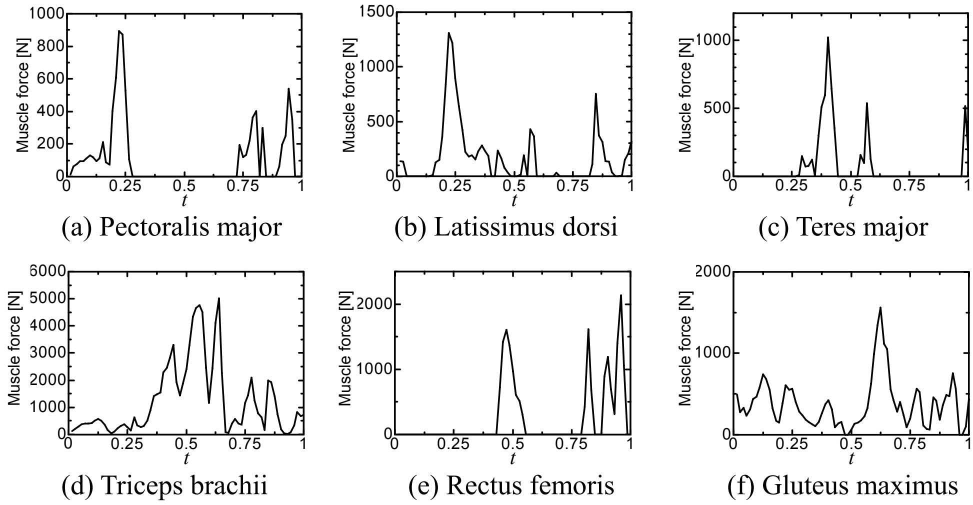


Figure 6. Muscle force for left side of the body (Butterfly stroke).

gravity and the reaction force against the flutter kick.

Butterfly stroke

The simulation results of the butterfly stroke are shown in Figs.5 and 6. With respect to the upper limb, it is found that pectoralis major, latissimus dorsi, teres major become active during the pull motion (t = 0.25~0.375), and that triceps brachii becomes significantly active during the push motion (t=0.375~0.625), in which the largest thrust is obtained. With respect to the lower limb, rectus femoris becomes active corresponding to the two down kicks (t = 0.5 and t = 0.875~1). It is also found that gluteus maximus becomes active just after the first down kick (t=0.625) in order to pull up the thighs for preparing the following second down kick.

CONCLUSION

In this study, the musculoskeletal simulation for the three swimming strokes was conducted. Many reasonable tendencies were obtained in the simulation results.

However, most of the time histories of muscle force exhibit unreasonable high frequency fluctuation. In addition, the absolute values in some results seem unreasonably large. Therefore, future work has to include the improvement of the quantitative accuracy of the simulation and the experimental verification of the simulation results. The authors believe that the musculoskeletal simulation for swimming will be a powerful tool to assess the swimming motion, when those problems are solved.

This work was funded by Grant-in-Aid for Scientific Research (No. 18650175) from the Japan Society for the Promotion of Science.

REFERENCES

1. AnyBody Technology. http://www.anybodytech.com/
2. Ikai M, Ishi K, Miyashita M (1964). An electromyographic study of swimming. Research J Physical Education, 7(4): 47-54.
3. Nakashima M (2007). Mechanical study of standard six beat front crawl swimming by using swimming human simulation model. J Fluid Science and Technology, 2(1): 290-301.
4. Nakashima M (2007). Analysis of breast, back and butterfly strokes by the swimming human simulation model SWUM. In: Kato N and Kamimura S (eds.). Bio-mechanisms of Swimming and Flying -Fluid Dynamics, Bio-mimetic Robots, and Sports Science-: Springer, 361-372.
5. Nakashima M, Motegi Y (2007). Development of a full-body musculo-skeletal simulator for swimming. Proc 11th Int Symp on Computer Simulation in Biomech, 59-60.
6. Nakashima M, Satou K, Miura Y (2007). Development of swimming human simulation model considering rigid body dynamics and unsteady fluid force for whole body. J Fluid Science and Technology, 2(1): 56-67.
7. SWUM Developer Team. http://www.swum.org/

Simulation analysis of the effects of undulation amplitude change on the performance during the underwater dolphin kicking

Seiji Sugimoto[1], Motomu Nakashima[2], Takeo Nomura[1]

[1] University of Tsukuba, Ibaraki, Japan

[2] Tokyo Institute of Technology, Tokyo, Japan

The purpose of this study was to investigate the relationship between undulation amplitude and underwater dolphin kick performance using the simulation model SWUM[1] (SWimming hUman Model). The input data for the SWUM measured from eight elite male competitive swimmers (age 21.4±1.1 yrs., height 173.6±90 cm, weight 70.0±8.7 kg), and the simulations that were changed the undulation amplitude executed to estimate the change of the swimming velocity, thrust generated by the feet and the joint torques generated by the trunk, hip and knee joints. This result indicated that the swimmers can improve their performance by changing their undulation amplitude during the underwater dolphin kicking without generating larger joint torques than usual. Consequently it was quantitatively concluded that the undulation amplitude during the underwater dolphin kicking was important in the performance.

Key words: *fluid dynamics, thrust, joint torque*

INTRODUCTION

After a start and a turn in the competitive swimming race, the underwater dolphin kick is used in the all swimming style. Since the use of the underwater dolphin kick is accepted to a maximum of 15 m in the butterfly, backstroke and front crawl events, the underwater dolphin kick greatly contributes to the performance of these events.

During the underwater dolphin kicking, the swimmers let a whole body undulate on sagittal plane and generate the main thrust by the feet[2]. Therefore it is assumed that the undulation during the underwater dolphin kicking is an important movement to control the performance.

The purpose of this study was to investigate the relationship between undulation amplitude and underwater dolphin kick performance using the simulation model SWUM[1] (SWimming hUman Model).

METHODS

1. Simulation input data

The entire body was represented as the series of elliptic cylinders in this simulation. Three unsteady fluid forces (added mass force, normal and tangential resistive force), buoyancy and gravity acting on the elliptic cylinders were computed from the shapes and densities of the cylinders, and from the joint motion for one cycle. Eight elite male competitive swimmers (age 21.4±1.1 yrs., height 173.6±90 cm, weight 70.0±8.7 kg) participated in this study. Their physical characteristics were measured for the simulation input data (the shapes and densities of the elliptic cylinders). The joint motion data for one cycle were obtained from 2-D DLT method during the underwater dolphin kicking with two different velocities (Slow, Fast).

2. Simulation condition

To recreate the dynamics of the underwater dolphin kick on the simulation, three fluid coefficients, used to calculate the three unsteady fluid forces in the simulation, were identified to minimize the difference between measured and simulated swimming velocity by the least-squares method. This identification was conducted for each input data.

3. Simulation of the changed undulation amplitude

The simulations that were changed the undulation amplitude executed with the optimal fluid coefficients for each swimmer. The variations of the undulation amplitude of the entire body except the feet on sagittal plane were seven stages (rate of change -5 %: simulation that adapted change S_{J-5}, -3 %: S_{J-3}, -1 %: S_{J-1}, 0 %: S_{J0}, 1 %: S_{J+1}, 3 %: S_{J+3}, 5 %: S_{J+5}). The simulation (S_{JVinc}) that swimming velocity was the highest and the simulation (S_{JVdec}) that swimming was the lowest were compared with the simulation (S_{J0}) that was not changed the undulation amplitude about the swimming velocity, the thrust generated by the feet and the joint torques generated by the trunk, hip and knee joints. Furthermore, the comparison of the required 10 m time was performed to investigate the influence on the concrete performance.

4. Statistical analysis

Dunnett's multiple comparison test (MANOVA) were used for analyzing the difference in each mean value of the swimming velocity, required 10 m time, thrust, and joint torques. Statistical significance was defined as $p < .05$.

RESULTS

The change of mean swimming velocity for S_{JVinc} increased 0.03±0.02 m/s ($p < .05$) significantly and that for S_{JVdec} decreased -0.02±0.02 m/s ($p < .05$) significantly at th Slow (Table 1). For the Fast, S_{JVinc} increased 0.01±0.01 m/s ($p = .39$) and S_{JVdec} decreased -0.02±0.03 m/s ($p = .05$). The mean required 10 m time about S_{JVinc} shortened -0.21±0.14 m/s ($p < .05$) significantly and that about S_{JVdec} extended 0.20±0.13 m/s ($p < .05$) significantly at the Slow. About the Fast, S_{JVinc} shortened -0.04±0.05 m/s ($p = .32$) and S_{JVdec} extended 0.08±0.09 m/s ($p < .05$) significantly. The swimming velocities and required 10 m times changed by the undulation amplitude change.

Although the mean thrusts generated by the feet (Table 2) did not changed significantly, that changes were classified in two types (Type 1: The thrust increased in S_{JVinc} and decreased in S_{JVdec}, Type 2: The thrust increased in S_{JVdec} and decreased in S_{JVinc}).

The joint torques generated by the trunk, hip and knee joints (Table 3) about S_{JVinc} and S_{JVdec} did not changed significantly.

Table 1 Velocity and 10m time changes by undulation amplitude changes.

Subject		S_{J0} velocity [m/s]	S_{J0} 10m [s]	S_J	S_{JVinc} velocity (Δv) [m/s]	S_{JVinc} 10m (Δt) [s]	S_J	S_{JVdec} velocity (Δv) [m/s]	S_{JVdec} 10m (Δt) [s]
Slow	A	1.00	10.04	S_{J-5}	1.02 (0.023)	9.81 (-0.22)	S_{J+5}	0.99 (-0.008)	10.12 (0.079)
	F	1.14	8.75	S_{J-5}	1.19 (0.045)	8.42 (-0.33)	S_{J+5}	1.10 (-0.047)	9.13 (0.376)
	I	1.10	9.10	S_{J-3}	1.10 (0.002)	9.08 (-0.01)	S_{J+5}	1.08 (-0.021)	9.27 (0.178)
	Ka	1.25	7.97	S_{J-5}	1.28 (0.028)	7.79 (-0.18)	S_{J+5}	1.23 (-0.027)	8.14 (0.176)
	Ki	0.86	11.69	S_{J-5}	0.87 (0.016)	11.47 (-0.22)	S_{J+5}	0.84 (-0.016)	11.91 (0.229)
	O	1.05	9.48	S_{J-5}	1.06 (0.009)	9.40 (-0.08)	S_{J+5}	1.04 (-0.013)	9.60 (0.121)
	T	1.09	9.17	S_{J-5}	1.15 (0.057)	8.72 (-0.46)	S_{J+5}	1.09 (-0.004)	9.21 (0.033)
	W	1.30	7.68	S_{J-5}	1.33 (0.032)	7.50 (-0.18)	S_{J+5}	1.24 (-0.062)	8.06 (0.383)
Fast	A	1.44	6.94	S_{J-5}	1.45 (0.012)	6.88 (-0.06)	S_{J+5}	1.43 (-0.012)	6.99 (0.057)
	F	1.59	6.29	S_{J-5}	1.59 (0.006)	6.27 (-0.02)	S_{J+5}	1.57 (-0.016)	6.36 (0.065)
	I	1.84	5.43	S_{J+3}	1.85 (0.004)	5.42 (-0.01)	S_{J-5}	1.83 (-0.007)	5.45 (0.021)
	Ka	1.81	5.52	S_{J-1}	1.81 (0.001)	5.52 (0.00)	S_{J+5}	1.80 (-0.014)	5.57 (0.044)
	Ki	1.37	7.30	S_{J0}	1.37 (0.000)	7.30 (0.00)	S_{J+5}	1.37 (-0.002)	7.31 (0.011)
	O	1.71	5.83	S_{J-5}	1.72 (0.002)	5.82 (-0.01)	S_{J+5}	1.63 (-0.082)	6.12 (0.292)
	T	1.60	6.25	S_{J+1}	1.63 (0.031)	6.13 (-0.12)	S_{J+5}	1.60 (-0.003)	6.26 (0.011)
	W	1.51	6.64	S_{J-5}	1.53 (0.024)	6.53 (-0.11)	S_{J+5}	1.48 (-0.030)	6.77 (0.134)
Mean	Slow	1.10	9.23		1.13 (0.03)*	9.02 (-0.21)*		1.07 (-0.02)*	9.43 (0.20)*
	[SD]	[0.14]	[1.25]		[0.15] [0.02]	[1.26] [0.14]		[0.13] [0.02]	[1.22] [0.13]
	Fast	1.61	6.28		1.62 (0.01)	6.24 (-0.04)		1.59 (-0.02)	6.36 (0.08)*
	[SD]	[0.17]	[0.67]		[0.17] [0.01]	[0.65] [0.05]		[0.17] [0.03]	[0.65] [0.09]

* $p < 0.05$; ** $p < 0.01$

DISCUSSION & CONCLUSION

The swimming velocity changed due to the undulation amplitude changes during underwater dolphin kicking. The swimming velocity changes were classified into 3 types about increment (Type 1: decrement in the undulation amplitude and increment in the thrust, Type 2: decrement in the undulation amplitude and the thrust, Type 3: increment in the undulation amplitude and the thrust) and decrement (Type 1: increment in the undulation amplitude and decrement in the thrust, Type 2: increment in the undulation amplitude and the thrust, Type 3: decrement in the undulation amplitude and

Table 2 Thrust changes by undulation amplitude change.

Subject		S_{J0} Thrust [N]	S_{JVinc} Thrust (Δth_1) [N]	S_{JVdec} Thrust (Δth_2) [N]
Slow	A	19.71	21.25 (1.54)	19.03 (-0.68)
	F	20.94	20.34 (-0.60)	21.22 (0.27)
	I	37.50	38.02 (0.52)	36.62 (-0.88)
	Ka	25.63	25.41 (-0.22)	26.17 (0.54)
	Ki	18.90	19.09 (0.19)	18.57 (-0.34)
	O	24.01	24.05 (0.04)	23.22 (-0.79)
	T	23.83	26.23 (2.40)	23.37 (-0.46)
	W	35.34	36.94 (1.60)	33.66 (-1.67)
Fast	A	119.44	120.61 (1.17)	116.56 (-2.87)
	F	62.18	62.00 (-0.18)	62.25 (0.08)
	I	100.29	100.42 (0.13)	100.17 (-0.12)
	Ka	69.97	70.11 (0.14)	68.93 (-1.04)
	Ki	64.34	64.34 (0.00)	67.26 (2.92)
	O	80.26	82.31 (2.05)	77.65 (-2.60)
	T	63.61	64.21 (0.60)	62.09 (-1.52)
	W	50.68	51.18 (0.50)	50.44 (-0.25)
Mean	Slow	25.73	26.42 (0.68)	25.23 (-0.50)
	[SD]	[7.00]	[7.26] [1.04]	[6.63] [0.69]
	Fast	76.35	76.90 (0.55)	75.67 (-0.68)
	[SD]	[22.84]	[23.12] [0.74]	[22.02] [1.83]

* $p < 0.05$; ** $p < 0.01$

Table 3 Peak joint torque changes by undulation amplitude change.

	Slow (Nm)			Fast (Nm)		
	S_{J0}	S_{JVinc}	S_{JVdec}	S_{J0}	S_{JVinc}	S_{JVdec}
Hip joint	95±35	93±35	97±35	112±46	112±46	110±48
Knee joint	124±41	121±41	126±41	145±51	143±51	147±51
First joint (flexion)	109±46	107±44	113±45	166±70	168±73	160±69
First joint (extention)	-74±32	-75±31	-73±31	-127±47	-127±51	-130±45

* $p < 0.05$; ** $p < 0.01$

the thrust) respectively. The drag increases because the frontal projected area increases with an increment in the undulation amplitude and the drag decreases because the frontal projected area decreases with a decrement in the undulation amplitude. Therefore it was supposed that the swimming velocity changed because of the drag and the thrust changes due to the undulation amplitude changes. The joint torques generated by the trunk, hip and knee joints did not changed due to the amplitude changes. This result indicated that the swimmers can improve their performance by changing their undulation amplitude during the underwater dolphin kicking without generating larger joint torques than usual. Consequently it was quantitatively concluded that the undulation amplitude during the underwater dolphin kicking was important in the performance.

REFFERENCES

1. Nakashima M, Satou K and Miura Y (2005): Development of swimming human simulation model considering rigid body dynamics and unsteady fluid force for whole Body. Journal of the Japan Society of Mechanical Engineers B (71): 1361-1369 (in Japanese)
2. Sugimoto S, Nakashima M, Ichikawa H and Nomura T (2006): Estimation of thrusts generated by each body part during underwater dolphin kick using “SWUM”. In: Vilas-Boas JP, Alves F, Marques A (Eds), Biomechanics and Medicine in Swimming X. Portuguese Journal of Sport Sciences 6 (Suppl.2): 100-102

Oral presentation

Day 3 – 27th March

Room 2 - (201 B)

Development of the Multiple Regression Models for Estimating the Force in Tethered Swimming (TS) and the Power in Semi-Tethered Swimming (STS)

Toshinori Saijoh[1], Masaaki Ohba[2], Akira Shionoya[1]

[1] Nagaoka University of Technology

[2] Niigata University

The purposes of this study were to develop the systems, which measured the force in TS and the power in STS with ease and low cost and to investigate the relationships between the performance of swimming and force in TS and power in STS. Furthermore, the multiple regression models to estimate the force in TS and the power in STS were developed using several physical elements. The relationship between the force in TS and the power in STS in male was Y=1.82X-16.35 (R=0.902) and this relationship was highly significant statistically($p<0.001$). The relationship between the force in TS and the power in STS in female was Y=1.82X+9.44 (R=0.800) and this relationship was highly significant statistically($p<0.001$). Furthermore, the examples of the multiple regression model of the power in STS for male was aquired as follows;

Power in STS = 0.33*Height+0.37*Finger Span+0.10*Vertical Jump+0.03*VJP-91.066 (r=0.85)

Key words: *Tethered Swimming, Semi-tethered Swimming, Force, Power*

Introduction

In a swimming competition, it is important to perform the driving capacity of swimming. To evaluate the driving capacity of swimmer from point of biomechanics, two ways can be considered as follows: (1) force measurement in the tethered swimming (TS) (2) power measurement in the semi-tethered swimming (STS). These types of swimming are named a resisted swimming. The TS is the resisted swimming without the driving forward. On the other hand, the STS is the resisted swimming with driving forward. There are few systems which measure the assignment of these mechanical work rates of an exercise in water such as swimming. Moreover, already-existent systems such as the swim-mill, the water flow processor or the power processor for swimming are very expensive and difficult to operate.

The purposes of this study were to develop the systems, which measured the force in TS and the power in STS with ease and low cost and to investigate the relationships between the performance of swimming and force in TS and power in STS. Furthermore, the multiple regression models to estimate the force in TS and the power in STS were developed using several physical elements.

Methods

In this study, the systems, which measured the force in TS and the power in STS with ease and low cost were to developed. Fig.1 shows the system, which measured the force in TS. Force was measured by the electrical force gauge (IMADA: DPX-50T). Output signal from the force gauge was transformed by an A/D converter to be analyzed by a kinetic analysis system (ELMEC: DAQ-WIN Ver4.7) installed into a personal computer. Fig.2 shows the system, which measured the power in STS. This system was constituted with a unit of an ergometer on the market, as an exercise work load system and attachment drum coiling the long wire, which swimmer pulled. Fig.3 shows the attachment drum connected to one side of pedal of an ergometer. Each swimmer tried to pull a wire coiling around the attachment drum. Force in STS was measured by the above-mentioned electrical force gauge. Furthermore, velocity in STS was measured by the stepping permanent motor (Nippon Servo. KP3P8). The characteristics of this motor was N=0.167*Ds*p; provided that N was the rotation velocity, Ds was the stepping degree and p was the pulse rate. Output signals from the force gauge and stepping motor were transformed by an A/D converter and power in STS was calculated by the product of the force and velocity in STS. The force in TS and the power in STS were measured and the relationship between these assignments of mechanical work rate of an exercise in water and the swimming performance were investigated. Furthermore, the multiple regression models to estimate the force in TS and the power in STS were developed using several physical elements.

Over 100 subjects (Average of age in male was 14.1 (SD=1.7), female was 12.8 (SD=0.8)) were participated in the measurements of the force in TS and the power in STS. Measurement was done at the same time of swimming meet (Niigata sprint swimming competition 2005 and 2006) program. In both TS and STS, each subject was instructed to swim at full strength without kicking on the wall of the pool and to swim in TS and STS by the same event, which he swan at the above-mentioned swimming meet. Furthermore, height, weight, finger reach span, foot length and vertical jump in each subject were measured as physical elements. Vertical jump power was

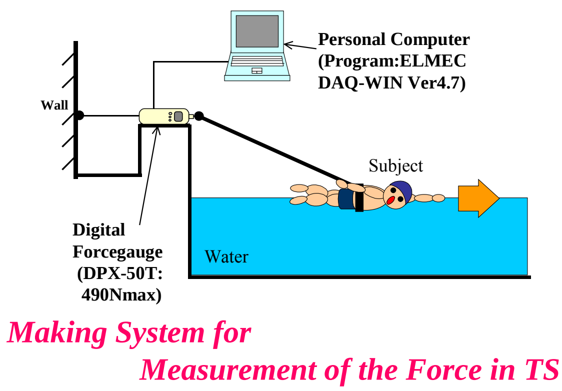


Figure 1. The system for measuring the power in TS

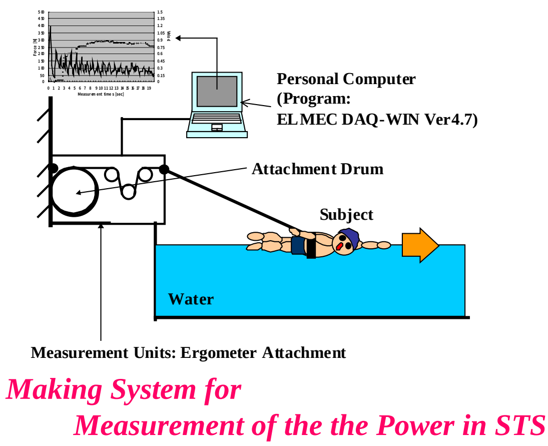
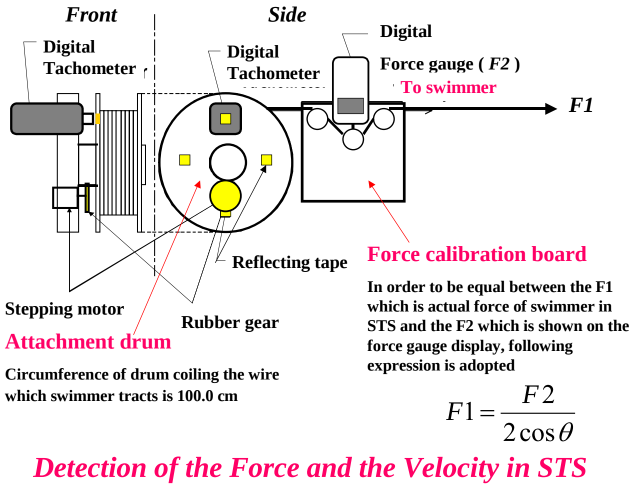


Figure 2. The system for measuring the force in STS



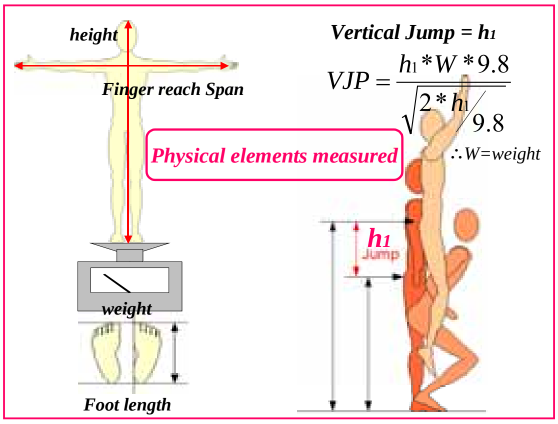


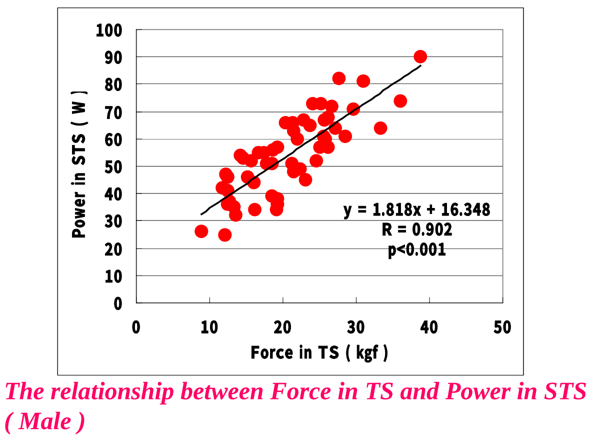
Figure 3. Attachment drum

Figure 4. Physical elements

calculated by the height of vertical jump. Furthermore, the multiple regression models to estimate the force in TS and the power in STS were developed using these physical elements (Fig.4).

Results

Fig.5 shows the relationship between the force in TS and the power in STS in male. This relationship was Y=1.82X-16.35 (R=0.902) and this relationship was highly significant statistically($p<0.001$).



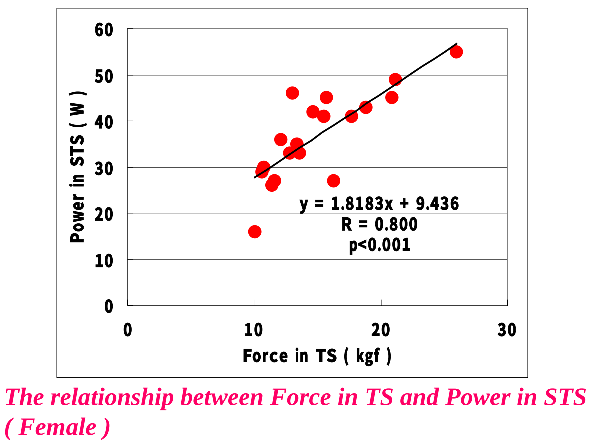


Figure.5 Relationship between force in TS and power in STS (Male)

Figure.6 Relationship between force in TS and power in STS (Female)

Fig.6 shows the relationship between the force in TS and the power in STS in female. This relationship was Y=1.82X+9.44 (R=0.800) and this relationship was highly significant statistically($p<0.001$).

Table. 1 shows the correlation matrix of the relationship between the force in TS, the power in STS and each physical elements in male. The element, which had high significant relationship ($R<0.700$, $p<0.001$) with the force in TS, was jump power.

The elements, which had high significant relationship ($R<0.700$, $p<0.001$) with the power in STS, were height, weight, finger reach span, foot length and jump power.

Table. 2 shows the correlation matrix of the relationship between the force in TS, the power in STS and each physical elements in female. The elements, which had high significant relationship ($R<0.500$, $p<0.05$) with the force in TS, were height and weight. The elements, which had high significant relationship ($R<0.500$, $p<0.05$) with the power in STS, were height, finger reach span and jump power.

The multiple regression models to estimate the force in TS and the power in STS

The multiple regression models using height, weight, finger reach span, foot length, vertical jump and vertical jump power as physical elements of swimmers, could be

Table.1 Correlation matrix in male

Correlation Matrix in Male *Number=53*

	STS	TS	Height	Weight	Age	Finger span	Foot length	Vertical Jump	Jump power
STS		0.902 ***	0.799 ***	0.785 ***	0.744 ***	0.780 ***	0.704 ***	0.559 ***	0.815 ***
TS	0.902 ***		0.666 ***	0.680 ***	0.650 ***	0.658 ***	0.674 ***	0.600 ***	0.750 ***
Height	0.799 ***	0.666 ***		0.863 ***	0.736 ***	0.924 ***	0.861 ***	0.455 ***	0.835 ***
Weight	0.785 ***	0.680 ***	0.863 ***		0.671 ***	0.800 ***	0.755 ***	0.448 ***	0.934 ***
Age	0.744 ***	0.650 ***	0.736 ***	0.671 ***		0.672 ***	0.604 ***	0.528 ***	0.715 ***
Finger span	0.780 ***	0.658 ***	0.924 ***	0.800 ***	0.672 ***		0.834 ***	0.438 **	0.779 ***
Foot Length	0.704 ***	0.674 ***	0.861 ***	0.755 ***	0.604 ***	0.834 ***		0.471 ***	0.763 ***
Vertical Jump	0.559 ***	0.600 ***	0.455 ***	0.448 ***	0.528 ***	0.438 **	0.471 ***		0.733 ***
Jump power	0.815 ***	0.750 ***	0.835 ***	0.934 ***	0.715 ***	0.779 ***	0.763 ***	0.733 ***	

Significance statistically in *0.05, **0.01, ***0.001

Table.2 Correlation matrix in female

Correlation Matrix in Female *Number=50*

	STS	TS	Height	Weight	Age	Finger span	Foot length	Vertical Jump	Jump power
STS		0.800 ***	0.517 ***	0.476 ***	0.017 N.S	0.504 ***	0.167 N.S	0.395 **	0.612 ***
TS N=19	0.800 ***		0.584 **	0.511 **	0.187 N.S	0.465 *	0.319 N.S	0.161 N.S	0.439 *
Height	0.517 ***	0.584 **		0.720 ***	0.105 N.S	0.812 ***	0.636 ***	0.179 N.S	0.681 ***
Weight	0.476 ***	0.511 *	0.720 ***		0.378 **	0.620 ***	0.532 ***	0.032 N.S	0.811 ***
Age	0.017 N.S	0.187 N.S	0.105 N.S	0.378 **		0.126 N.S	0.182 N.S	0.01 N.S	0.274 *
Finger span	0.504 ***	0.465 *	0.812 ***	0.620 ***	0.126 N.S		0.636 ***	0.326 *	0.694 ***
Foot Length	0.167 N.S	0.319 N.S	0.636 ***	0.532 ***	0.182 N.S	0.636 ***		0.071 N.S	0.374 **
Vertical Jump	0.395 **	0.161 N.S	0.179 N.S	0.032 N.S	0.01 N.S	0.326 *	0.071 N.S		0.605 ***
Jump power	0.612 ***	0.439 *	0.681 ***	0.811 ***	0.274 *	0.694 ***	0.374 **	0.605 ***	

Significance statistically in *0.05, **0.01, ***0.001

approximated to the force in TS and the power in STS, the significant models were confirmed. These models could be approximated and evaluated the force and the power without measurements of these. The examples of the multiple regression models for male were as follows;

Power in STS =

0.35*Height+0.58*Weight+0.42*Finger Span+0.44*Foot Length -104.450(r=0.828)

Power in STS =

0.33*Height+0.37*Finger Span+0.10*Vertical Jump+0.03*VJP-91.066 (r=0.85)

Force in ST =

0.01*Height+0.16*Finger Span+0.14*Vertical Jump+0.02*VJP-25.27 (r=0.767)

Force in ST =

0.2*Height+1.33*Foot Length+0.13*Vertical Jump+0.2*VJP-33.789 (r=0.773)

These models could promote the talent finding and the training of swimmer.

References

1. Shionoya A, Ohba M, Miyake H. (2005). Force measurement in tethered swimming and power measurement in semi-tethered swimming. The impact technology on sport. 1: 367-372.
2. Shionoya A, Ohba M, Ito K and Shibukura T. (2008). Significance on the measurement of the force in the Tethered Swimming for the primary school swimmer—Multiple regression model making using the physical elements and fitness tests—. Report of Niigata prefectural women's college. In print.

Method of establishing individual level of kinesthetic differentiation ability in water environment

Andrzej Klarowicz, Krystyna Zatoń, Piotr Albiński
Department of Swimming University School of Physical Education Wroclaw, Poland

The level of kinesthetic differentiation described in literature is as a human coordinative ability, which essentially determine ability to orientate in space. Usually all tests measuring level of kinesthetic differentiation are carried in laboratorial circumstances. It is not taken in consideration the specifics of environment where the determined motor activity is carried out. For his reason the aim of the study is to determine level of kinesthetic differentiation directly in water. The study was carried out with the use of kinaesthesiometer, which was specially designed to record changes of propulsive force. The device records the movement of the subject, which aim at conscious differentiation of force in water. Each movement made by the subjects is controlled by their consciousness and result of the movement generates propulsive force. The propulsive force, time and total impulse were the parameters to determine level of kinesthetic differentiation.

Key words: *swimming, kinesthetic, differentiation, force, communications*

INTRODUCTION

The research on conscious reception of kinaesthetic sensations are carried out in numerous scientific centres both in Poland (Warsaw, Poznan, Krakow) and abroad. This problem has been described in literature based on various didactic theories. The first significant theory understands the ability of conscious sensations reception by the learner as one of the factors assuring correct spatial orientation (natural and water environment). The process of familiarizing new space like water environment is long-lasting and complex. We experience the space by looking at and especially by moving in it. Getting from one place to another one gains the sense of direction (Taun 1987). While moving in space we gain various experiences and observations which provide us with information about the space and ability to orient oneself in it (Taun 1987) and only by comprehending it completely are we guaranteed with free movement and realisation of our possibilities. To sum up, spatial orientation is an image of ones body scheme, knowledge of directions and location in space. It is based on visual, tactile, aural and kinesthetic sensations (Kephart1970, Głodkowska2000). Theory understanding conscious reception of kinesthetic experiences as coordination ability, expressed by the ability to differentiate power and repeat movement amplitude. The theory assumes also existence of kinesthetic-movement analyser. It gathers information from proprioreceptors and interoreceptors which is then analysed in cerebral cortex and changed into proper reaction of the organism. Numerous definitions of kinesthetic differentiation have been created within the last few decades. According to them kinaesthetic differentiation is a subtle differentiation of proprioreceptive stimuli appearing while moving limbs in water environment. The newest definition assumes that these are coordination abilities enabling full adaptation to the environment and rational movement with the use of minimum energy (Starosta 1998).

AIM OF STUDY

Research on muscle strength momentum and range of joint movement have been carried out in order to asses the size of kinesthetic differentiation. Such research allowed for individual demarcation in different groups, depending on age of the subjects, sport discipline and physiological organism capabilities. All research were carried out in laboratory conditions. Environment specificity, in which certain human movement activity takes place, has not been taken into account. The aim of the study is to determine level of kinesthetic differentiation abilities directly in water environment.

Hypothesis:

- Values of the integral impulse allow to determine the level of kinesthetic differentiation ability in water.
- People of higher level of kinesthetic differentiation ability move more effectively in water.

METHODS

Group of children between 8 and 12 years of age took part in the research. It coincided with swimming lessons programme whose aim was to cover swimming techniques at a standard level. The lessons took place in a 25m pool at University School of Physical Education in Wroclaw. Along with the group of learners also younger swimmers (aged 10-14) as well as juniors and seniors (aged 15-22) were examined. Altogether 120 subjects took part in the research. The first stage of the research involved series of experiments conducted in laboratory conditions. The main aim of this part of the study was to record conscious learner’s reactions to verbal instructions given by teacher. It was possible thanks to a research post designed in the Swimming Department of Wroclaw Sport Academy, where even the nonswimmers could participate in the research. It consists of a tensometric platform, a bench, slow alternating signals booster and a computer. Pictures 1, 2 present all elements of the device. The platform was placed in water so that each subject could remain in a sitting position. The level of bench was adjusted individually depending on subject’s body height. Head of the subjects was not submerged. Such a position guaranteed easy breathing increasing comfort of the research (picture 3).

Picture 1,2,3

In the research the subjects performed adductive arm movements in water with the highest possible precision. The subject’s attention was focused on sensing water resistance. During the arm movements pull force changes were recorded by sensors. Those changes were a direct result of a conscious behaviour in water environment. The device allowed to record force of 100 Hz frequency. It has been assumed in the study that there exists a cause and effect relationship between the teacher’s words and the platform data record. The diagram below illustrates this relationship.

Instruction:” Make 10 underwater pulls with the same force”

Performing the movements with conscious focus on sensations received from water environment.

Pull force (F) evoked by the paddle movement.

Tensometric platform record of F values changes in the time function

Graphic illustration of student’s reaction to the verbal instruction.

Thus, measurement of the student's reaction to "information making him/her aware of the kinaesthetic sensations" and assessment of their effectiveness becomes possible. Figure 1 presents record of student's reaction to information making him/her aware of the kinesthetic sensations.

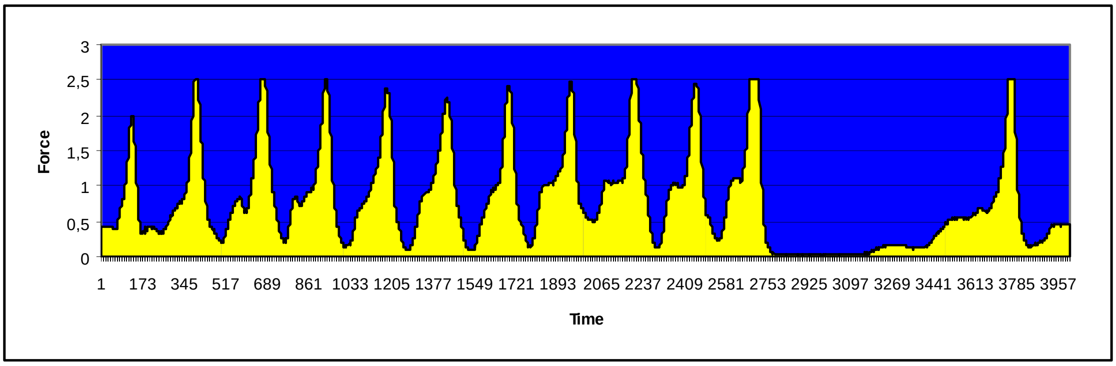


Figure 1. Momentum forces during test for kinesthetic differentiation ability in water.

Parameters describing level of kinesthetic sensitivity: pull force, time and integral impulse (momentum change).

$$\mathbf{I = F\Delta t}$$

The formula for alternating force:

$$\mathbf{I = \int F\, dt}$$

where

I: impulse of a force F,

F: force,

t: time.

The impulse unit is N·s = Kg·m/s sometimes referred to as Huygens and noted as Hy. Additionally, level of swimming effectiveness was also determined among the subjects. For this reason time of free swim at the 25m distance was measured. Following levels of swimming effectiveness have been determined:

- Low (can't swim)
- Average (time between 20s -40s).
- High (20s -15s).

- The highest (15s and less).

RESULTS AND DISCUSSION

This simple record allowed to collect values reflecting numerically the phenomenon of conscious force differentiation in water.

The research has established that the value of integral impulse (momentum change) measured in a constant time unit (1 second) differentiates the group of the subjects. Figure 2 presents the correlation between the swimming effectiveness and the values of the integral impulse (marked as **Ic**).

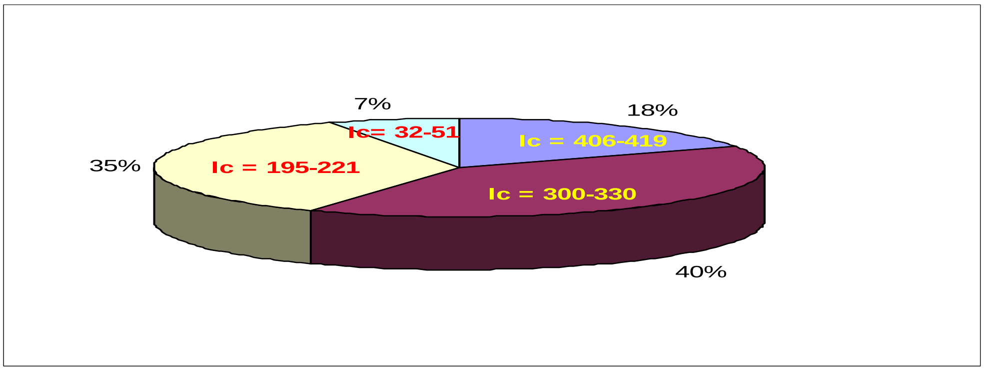


Figure 2. Integral impulse (Ic) values in the research groups.

The fewest, only 7% of the subjects, presented the lowest, zero level of swimming effectiveness (those who could not swim). The integral impulse value fluctuated between 32 and 51 Hy (N·s). People of the average swimming effectiveness had minimal Integral impulse value at the level of 195Hy and the maximal at the level of 221 Hy. This group constituted 35% of the subjects. High level of swimming effectiveness was presented by 40% of the researched. Their level of integral impulse fit between 300 and 330 Hy. The highest swimming effectiveness was presented by 18% of the subjects and their Integral impulse values reached 419 Hy.

CONCLUSIONS

There is a statistically significant relationship between the integral impulse value and swimming effectiveness. Correlation between the age of the subjects and the integral impulse value has not been found. Despite numerous publications on determining the level of kinesthetic differentiation ability (Wołk. R. Zatoń M. 1998, Starosta W. 1998, Zatoń K. 1981, Zatoń K. Klarowicz A. 2006), no material describing the changes of these abilities directly in the water environment was found. The most frequent indicator specifying differentiation was the value of the average mathematical error (standard deviation). The measurement of the value of force coming as a result of conscious reception of stimuli from the water environment seems to be a pioneer concept. Would it be possible to find correlation between the speed of swimming and the information passed on to the students by the teacher, its content and form? This question is waiting to be answered. Few studies written on the theory of the school physical education try to solve this problem. The method applied in the studies specifies the results of the conscious performance of a human in the water environment. We are not able to record the human thought but we can measure its effects and draw conclusions that in the future would give a more detailed knowledge on the teaching process of learning of the movement activities.

REFERENCES

1. Klarowicz A., Zatoń K. (2006) “Changes in kinesthetic differentation during program of fitness swimming for students”. Annales Universitatis Mariae Curie-Skłodowska Lublin – Polonia section D Medicina Vol.LX, Suppl. XVI, 291. s 258-261
2. Starosta W. (1994) Wpływ uprawianej dyscypliny sportowej na kształtowanie się u zawodników symetrii i asymetrii wrażeń kinestetycznych. Antropomotoryka. Nr. 11 s. 101-119.
3. Starosta W. (1998) Odświeżanie i budzenie wrażeń kinestetycznych-nowa metoda doskonalenia techniki sportowej. Trening II s. 41-46.
4. Tuan, Yi-Fu.(1987) Przestrzeń i miejsce, Warszawa, PIW.
5. Wołk. R. Zatoń M. (1998) Zależność pomiędzy zdolnością różnicowania kinestetycznego a motorycznym uczeniem się. III Interdyscyplinarna Krajowa Konferencja. Mat. Nauk. Warszawa – Spała.
6. Zatoń K. Zatoń M. (1998) *Znaczenie słowa w nauczaniu i doskonaleniu techniki sportowej*. [w:] Aktywność ruchowa w świetle badań fizjologicznych i promocji zdrowia pod red. M Zatonia, Z. Jethona AWF Wrocław, S. 63-6

Factors of improved swimming performance by wearing a triathlon wetsuit

Masamitsu Tomikawa [1], Takeo Nomura [2]

[1] KEN'S CO., LTD, Japan

[2] University of Tsukuba, Faculty of Comprehensive Human Science, Japan

This study was aimed to clarify the effects of wearing a triathlon wetsuit (WS) on performance-determining factors during swimming and to determine the factors in improved swimming performance during triathlon races when wearing a WS. Less power to overcome drag was required at a given velocity and triathletes were able to swim in faster speed. Furthermore, wearing a WS could delay accumulation of fatigue by lessening the energy used for buoyancy and postural stability, and work completed by the arms increased without increasing entire exercise intensity in a WS condition. Therefore, improved swimming performance by wearing a WS was attributable merely to the utmost use of the limited physical performance capacity, i.e. the improvement in propulsion efficiency, and was dependent more on incremental changes in stroke rate than stroke length.

Key words: *stroke rate, stroke length, oxygen consumption, power output, efficiency, fatigue*

INTRODUCTION

A considerable amount of evidences clarify that wearing a WS helps to improve swimming performance compared with wearing a swimsuit (SS) [1, 2, 5, 6, 7, 9]. Performance-determining factors during swimming are categorised into those related to physical performance capacity, such as maximal oxygen consumption ($\dot{V}O_2max$) and maximal mechanical power output (POmax), in addition to those related to technique, such as stroke parameters (mechanical efficiency) and energy efficiency [10]. Thus, improved swimming performance by wearing a WS is supposed to be attributable to the improvements in some of these performance-determining factors. To investigate the effects of wearing a triathlon wetsuit (WS) on performance-determining factors, this study was designed to compare performance and stroke parameters between a WS and a swimsuit (SS) in relation to physiological responses at maximal effort, at the same absolute velocity and at the same relative velocity, respectively. Finally, this study attempts to clarify the factors related to improved performance during triathlon swims and to give some suggestions to improve performance in triathlon races when wearing a WS.

METHOD

Subjects and suit conditions.

A total of 25 triathletes, who had mainly competed in the Olympic distance triathlon, participated in this study as subjects. Their age ranged from 18 to 30 years. Seven subjects had competed in some international triathlon races in the elite category and others had taken part in the Japan national triathlon championships and/or inter-college triathlon championships. WS used in this study, which were custom-made for each subject, were made of neoprene and covered the torso, the arms to the wrist and the legs to the ankles. Swimsuits (SS) used in this study were conventional competitive swimsuits of each subject.

Experimental researches.

This study was composed by three sections as follows; 1) the first was to verify whether wearing a WS affect $\dot{V}O_2$max, POmax, and the relationships between these physical performance capacities and the associated performance during 400 m (V400) or sprint swim (Vsprint), 2) the second was to clarify the effects of wearing a WS on stroke parameters in relation to passive drag (PD) and $\dot{V}O_2$ at the same absolute velocity and the contribution of stroke rate (SR) and stroke length (SL) to improved performance during 400 m swim for each 50 m lap, and 3) the third was to compare a WS to a SS at the same relative velocity during submaximal swimming [60% of the velocity at which $\dot{V}O_2$max was achieved (V$\dot{V}O_2$max): $V_{60\%}$ and 80% of V$\dot{V}O_2$max: $V_{80\%}$] and to investigate the effect of wearing a WS on stroke parameters in relation to physiological responses. The effects of wearing a WS were investigated by comparing with a SS.

RESULTS AND DISCUSSION

Section 1.

In the WS condition, although V$\dot{V}O_2$max, V400 and Vsprint were increased by 6.0%, 7.1% and 4.3%, respectively, no differences were observed in $\dot{V}O_2$max and POmax between the two suit conditions. These suggest that increased V400 and Vsprint with a WS seem to be attributable to the improvement in technical factors and the utmost use of the limited physical performance capacity. Furthermore, a significant correlation was found between V400 and $\dot{V}O_2$max and between Vsprint and POmax in both suit conditions. However, when a WS worn, the relationship was higher than with a SS. These results suggested that wearing a WS would offset the variability in stroke techniques among individuals to some extent and the swimming performance would more reflect the amount of physical performance capacity.

Section 2.

When wearing a WS, PD was reduced through the towing test, although these effects were greater at lower velocity than at higher velocity. $\dot{V}O_2$ indicated just the same tendency as in PD. When wearing a WS, $\dot{V}O_2$ for buoyancy seem not to be required because the added buoyancy is sufficient to float the swimmer's body on water, thus, less power to overcome drag during swimming at a given velocity is required with WS. SR with a WS was lower than that with a SS, meanwhile, SL was larger in the WS condition. Contrary to the tendency that the effect of wearing a WS on PD and $\dot{V}O_2$, which was decreased with increasing velocity, the effect on SL tended to be greater gradually. Furthermore, SLPP (stroke point peak point) [8] in the WS conditions was attained at a higher velocity than in the SS condition. SLPP speed and the maximal lactate steady state (MLSS) speed [4] are highly correlated, and when swimming above MLSS speed, a loss of SL is induced probably related to local muscle fatigue and a declined ability to develop the force necessary to overcome the resistance to forward movement [3]. Therefore, wearing a WS could delay in accumulation of fatigue and improve mechanical efficiency by shifting the energy used for buoyancy to those used for propulsion and to cut out the need of the energy used for postural stability.

During 400 m swims, SL and SR were larger with a WS than that with a SS. The difference in SL tended to increase during the first 200 m, and thereafter managed to maintain it and that in SR were gradually increased form the 4th to the last lap same as the velocity. The increments in Velocity toward the last might attribute to alterations in SR. Wearing a WS would lessen fatigue in middle stage during maximal 400 m swim as compared to wearing a SS. Thus, when wearing a WS, triathletes could further the exertion to swim at maximal effort, and obtain a higher SR and a greater velocity.

Section 3.

Both $V_{60\%}$ and $V_{80\%}$ with a WS were higher by about 5% than those with a SS. At $V_{60\%}$, wearing a WS significantly decreased by 9.4% in $\dot{V}O_2$, but no difference was found at $V_{80\%}$. Cs (the energy cost of swimming) with a WS were significantly lower than those with a SS, but the differences in Cs between suit conditions were 14.4% at $V_{60\%}$ and 7.5% at $V_{80\%}$. The advantageous effects of wearing a WS are greater at a relative lower swimming velocity than a relative higher swimming velocity. However, even if subjects have similar $\dot{V}O_2$, they swim much faster with a WS and the triathlon swim would have a consequently shorter time, requiring less overall energy to cover the total distance.

No difference in SL was found between the two suit conditions, meanwhile, SR tended to be higher than with a SS at the same relative velocities. These results showed that work for the arms increased with a WS as a greater SR and an unchanged SL implied, nevertheless the subjects in the WS condition had similar or lower $\dot{V}O_2$ compared to the SS condition. Furthermore, this study found that the increment ratio of SR was related to the performance improvement ratio at the pace corresponding to triathlon swimming. Improved swimming performance by wearing a WS would depend more on the changes in SR rather than in SL.

CONCLUSION

Wearing a WS enables subjects to reduce the energy used for buoyancy and concentrate it on arm propelling motion instead without increasing $\dot{V}O_2$. Furthermore, when wearing a WS, to maintaining a higher SR seems to be important for performance at the pace during triathlon races.

REFERENCES

1. Chatard, J. C., X. Senegas, M. Selles, P. Dreanot, and A. Geyssant, (1995). Wet suit effect: a comparison between competitive swimmers and triathletes. Med Sci Sports Exerc, 27(4): 580-586.

2. Cordain, L. and R. Kopriva, (1991). Wetsuits, body density and swimming performance. Br J Sports Med, 25(1): 31-33.

3. Craig, A. B., P. L. Skehan, J. A. Pawelczyk, and W. L. Boomer, (1985). Velocity, stroke rate and distance per stroke during elite swimming competition. Med Sci Sport Exerc, 17(6): 625-634.

4. Dekerle, J., X. Nesi, T. Lefevre, S. Depretz, M. Sidney, F. Huot-Marchand, and P. Pelayo, (2005). Stroking parameters in front crawl swimming and maximal lactate steady state speed. Int J Sports Med, 26: 53-58.

5. De Lucas, R. C., P. Balikian, C. M. Neiva, C. C. Greco, and B. S. Denadai, (2000). The effects of wet suits on physiological and biomechanical indices during swimming. J Sci and Med Sports, 3: 1-8.

6. Lowdon, J. B., D. McKenzie, and B. R. Ridge, (1992). Effects of clothing and water temperature on swim performance. Aust J Sci Med Sport, 24(2): 33-38.

7. Nicolaou, K. D., J. M. Kozusko, and P. A. Bishop, (2001). The effects of wetsuits on swim performance. J Swimming Research, 15: 20-26.

8. Nomura, T., and Y. Shimoyama, (2003). The relationship between stroke parameters and physiological responses at the various swim speed. In: Chatard, J. C. (eds): Biomechanics and Medicine in Swimming IX. University of St-Etienne, St-Etienne, 355-360.

9. Parsons, L. and S. J. Day, (1986). Do wet suits affect swimming speed? Br J Sports Med, 20(3): 129-31.

10. Toussaint, H. M., and P. J. Beek, (1992). Biomechanics of competitive front crawl swimming. Sport Med, 13(1): 8-24.

A difference of blood lactate level in freestyle swimming between S-shaped and I-shaped stroke

Shinichiro Ito[1], Takaaki Matsumoto[2] and Daisuke Abe[3]
[1] Department of mechanical engineering, National Defense Academy,
1-10-20 Hashirimizu, Yokosuka,239-8686, Japan, E-mail:ito@nda.ac.jp
[2,3] School of Sports System, Graduate School of Kokushikan University,
7-3-1 Nagayama, Tama, Tokyo, 206-8515,
Email: [2] takaaki@kokushikan.ac.jp, [3]tpa517_butterfly@yahoo.co.jp

One of the authors proved that the calculation results which showed I-shaped pull stroke in freestyle stroke: The drag pull generates the maximum impellent. While the conventional S-shaped pull stroke provides the maximum efficiency. The result obtained here is mechanical efficiency, and it is distinct for physiological efficiency. S-shaped pull is shifted easily to the anaerobic motion in a high stroke pitch with a heavy load. As a result, the blood lactate accumulates in muscles to get tired. However, with the I-shaped pull, the stroke pitch cannot get so high that the I-shaped pull is not easy to become anaerobic motion because of the heavy load to the arm originally.
The authors measured the blood lactate and heart rates with both pulls at a fast speed at the almost same time with a swimmer who mastered both pulls. As a result, it was found that physical load of I-shaped pull is less than that of S-shaped pull at the same fast swimming speed.

Key words: *blood lactate, S-Shaped, I-Shaped, maximum, thrust, efficiency*

INTRODUCTION

James Counsilman [1] established a foundation of the present front crawl swimming style. He proposed a S-shaped pull stroke by observing skillful swimmers' underwater images in 1968. The driving force generated from a palm in S-shaped pull stroke utilizes a dynamic lift and drag forces. One of the authors, Ito [2] analyzed a soft-shelled turtle's swim, and applied the propelling theory obtained from the turtle's stroke to the front crawl stoke of human swimming. The calculation results showed that S-shaped pull stroke was a movement which requires minimal energy. The stoke of the drag type is I-shaped stroke which produces the maximal thrust (speed). Comparing with the S-shaped stroke, the I-shaped stroke gained 11% more of the propelling force. But it had a disadvantage of 2.4% in the propelling efficiency. However, the mechanical efficiency does not necessarily correspond to the physiological inefficiency, namely fatigue which a swimmer feels.

Physiologically, a direct energy source of the muscular shrinkage movement is ATP. As an exercise strength level becomes higher, glycogen in a muscular cell is decomposed into lactic acid as an energy source in an anaerobic state, and lactic acid accumulates in muscles. The blood lactate cannot always explain fatigue, but the blood lactate level (*La*) is generally used as an index of exercise strength (load). In addition, a heart rate index (*HR*) is one of the exercise strength indices that we can measure by real time although indirect. In this presentation, the state where a swimmer feels fatigue easily in the same movement is defined as low movement efficiency physiologically.

In a high load state such as in competitive swimming, a stroke rate in S-shaped stroke becomes high and the exercise is apt to shift to an anaerobic stage. As a result, lactic acid accumulates for muscles to stop moving. However, when a stroke thrust becomes large in I-shaped stroke, the stroke rate decreases at the same swimming speed with S-shaped stroke. Therefore, it can be analogized that I-shaped stroke does not become anaerobic exercise easily even with the heavy load. In other words, even if the mechanical propelling efficiency of I-shaped stroke is low, physiological movement efficiency could be better.

METHOD

The authors measured a blood lactate level (*La*) and a heart rate (*HR*) of a swimmer who mastered both swimming styles, the I-Shaped stroke and the S-shaped in freestyle. The testee swimmer swam 200m at the aimed speed of 79, 83, 86, 92%*V*max (*V*max: Personal best speed, Personal best time, Fr200m 1‘57’’7) in each style. An interval between each trial was 15 minutes. The trial of S-shaped and I-shaped stroke left an interval of 12days to avoid each influence. A stroke rate of I-shaped pull is lower than that of S-shaped at the same speed because of the larger thrust force that I-shaped pull produces. Therefore, a number of strokes per 50m was counted to confirm a difference of a swimming style.

RESULTS AND DISCUSSION

Fig.1 shows a distance and a lap time when the trials are performed. Speed of both pulls shows uniform in the trials and it is understood for the swimmer to swim at the same

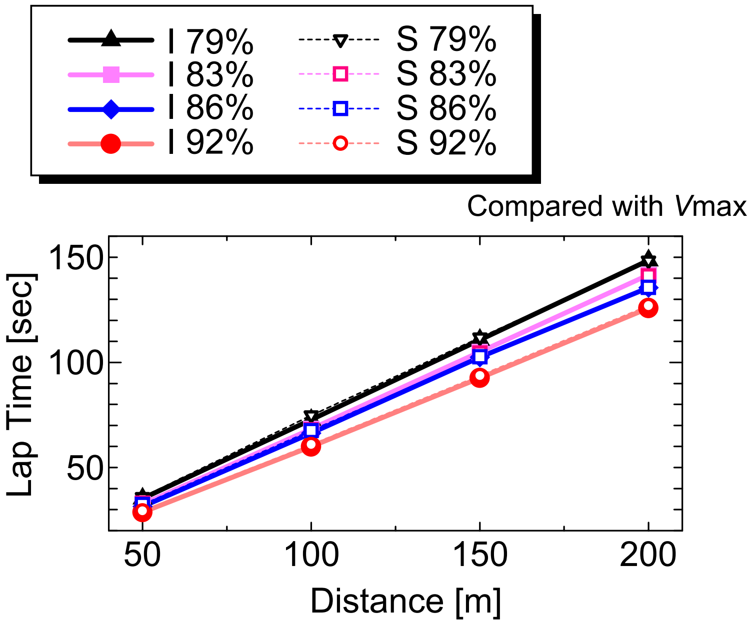


Fig.1 Time trial for OBLA tests with I-Shaped pull and S-Shaped pull stokes.

Table. 1 The Number of Strokes of every lap with I-Shaped pull and S-Shaped pull.

Swimming Lap Distance	Stroke type	79% *V*max	83% *V*max	86% *V*max	92% *V*max
0-50m	I-Shaped	25	25	25	26
	S-Shaped	27	27	28	29
50-100m	I-Shaped	26	26	26	28
	S-Shaped	28	30	30	34
100-150m	I-Shaped	26	26	26	28
	S-Shaped	28	30	30	34
150-200m	I-Shaped	27	27	27	29
	S-Shaped	29	31	31	35

time though the pull styles are different. Moreover, the number of strokes with each pull for every 50 meters is shown in Table 1. The number of the strokes in every 50m with I-shaped stroke is 28 in average, which are 6 strokes less than that with S-shaped at the same swim speed. In other words, I-shaped with less number of strokes achieves the same speed with S-shaped with more number of strokes

Fig.2 shows curves of blood lactate and that of heart rates under these experimental conditions. As the swim speed increases in the both swimming styles, the blood lactate levels (*La*) increases. The heart rates increase as well. At the lower swimming speed,

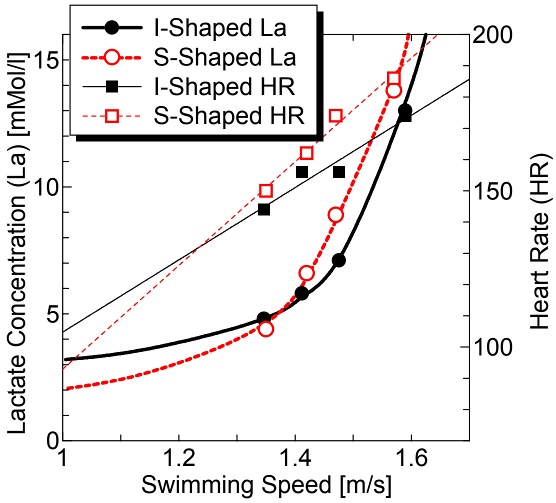


Fig.2 OBLA curves and Heart Rate curves with I-Shaped pull and S-Shaped pull.

I-shaped stroke produces a higher heart rate and a higher lactate level than S-shaped stroke. However the swim speed exceeds 1.24m/s in *HR* and 1.34m/s (79% *V*max) in *La*, the relationship between the two swimming styles reverses. Those of I-shaped stroke were smaller than those of S-shaped as the swim speed increases. The blood lactate level of I-shaped is -20% and -15% respectively compared with that of S-shaped in the degree of 86% and 93%*V*max. And it is similar that the heart rate of I-shaped is -6.8% and -9.1% compared with those of S-shaped at the same swim speed above. That is to say that a competitive swimmer with I-shaped stroke is hard to get tired.

CONCLUSION

Blood lactate level and heart rate were measured to confirm a fatigue level with S-shaped stroke and I-shaped pull in freestyle swimming at the same speed. As a result, both of the blood lactate level and the heart rate are lower with I-shaped stroke at higher swimming speed such as in a competitive swimming, although the mechanical propelling efficiency is lower in I-shaped than in S-shaped. Therefore, I-shaped pull causes less fatigue in a competitive swimming.

REFERENCES

1. Counsilman, J.E. (1968). Science of Swimming. Prentice-Hall, Englewood Cliffs, N.J.
2. Ito, S. and Okuno, K., (2003). Biomechanics and Medicine in Swimming IX, pp.39-44, Pub. de l'univ. de Saint-Etienne.

Analysis of the optimal arm stoke in the backstroke

Shinichiro Ito [1]

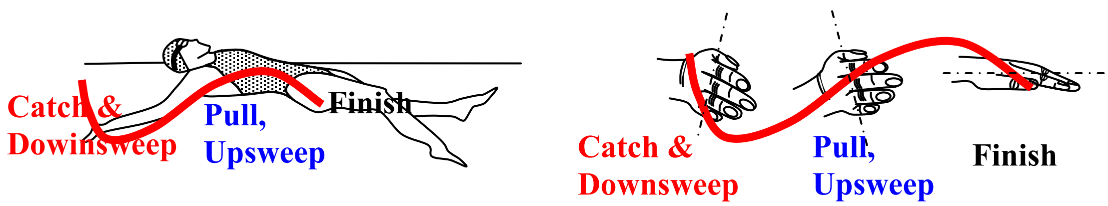
[1] Department of mechanical engineering, National Defense Academy,
1-10-20 Hashirimizu, Yokosuka, 239-8686, Japan, E-mail:ito@nda.ac.jp

The most general armstroke of the backstroke in a present competitive swimming is the so-called S-shaped stroke on a side of the body. The author calculated the optimal stroke in the backstroke with a simplified physical model by fluid dynamic characteristic of a palm obtained by a wind tunnel experiment. As a result, the optimal stroke path of the maximum efficiency and the maximum thrust were obtained as a driving angle, a tilt angle, and an angle of attack of a hand. The maximum efficiency was obtained in the S-shaped pull stroke on a side of the body, while the maximum thrust was obtained in the I-shaped pull stroke parallel to the body axis.

Key words: *backstroke, S-Shaped, I-Shaped, maximum, thrust, efficiency*

INTRODUCTION

Dynamics of swimming is fluid mechanics that acts on a swimmer and the water of the circumference of the body. James Counsilman (1968) proposed S-shaped pull swimming style is suitable for the front crawl in 1968. This S-shaped pull uses the resultant force of the lift and drag as an impellent. Lately, Sanders (1997) stated that competitive swimmers seem to use a drag type stroke rather than S-shaped pull stroke in his experimental research. Moreover, the author (Ito & Okuno, 2003) introduced I-shaped pull stroke, straight pull back stroke, obtained larger thrust force than S-shaped.



(a) Hand path of S-shaped back crawl.

(b) Hand posture in S-shaped back crawl stroke.

Fig.1 Side view of Conventional S-shaped backstroke.

As for the backstroke, it is often considered just as a turn over style of the front crawl stroke. However, it is not correct. Because of the different movable regions of shoulder joint, the backstroke takes a stroke on a side of the body shown in Fig.1 (a) or Fig.7 (a). In this study, I-shaped pull stroke was introduced in the backstroke besides S-shaped stroke, a conventional style for the backstroke. A palm plays a predominant role for an impellent in swimming according to previous studies by Hollander (1987) and Berger et al (1995). The posture angles and the driving angles of a palm which produced the maximum efficiency and the maximum thrust were calculated with the experimental data.

METHOD

A replica of a hand of a good swimmer was made with plaster. The fluid dynamic characteristics of the replica were examined in a wind tunnel in the same degree of the Reynolds number, Re=3.4×10^5, of the inflow speed to the hand of an actual swimmer. It is possible to divide a stroke of the backstroke into three phases as shown in Fig.1 (b), such as Catch (Downsweep), Pull (Upsweep), and Finish. Each phase is classified by sweepback angle ψ defined by Schleihauf (1979). The sweepback angle ψ is an angle of inflow into a hand palm as shown in Fig.2. It is possible to apply each phase into three kinds of degrees, 180°, 0°, and 45° respectively. Lift and drag forces were measured by three component load cells at every one degree of angle of attack from 0° to 90°. The obtained lift and drag forces were calculated into lift coefficient C_L and drag coefficient

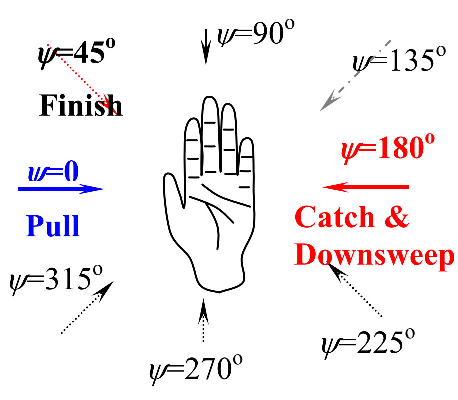


Fig 2 Sweepback angle ψ defined by Schleihauf (1979).

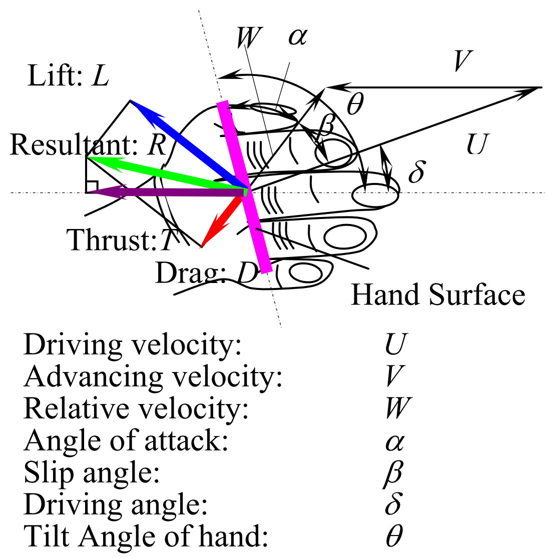


Fig. 3 Forces acting on a hand paddle.

C_D according to a projected sectional area of a hand palm S. Polar curves, lift-drag curves, were obtained as characteristics of the hand.

An inclined hand by tilt angle θ is moved diagonally with driving velocity U and driving angle δ while a body moves with advancing velocity V shown in Figs. 4 in the backstroke. As a result, relative velocity W flows into the hand with angle of attack α. Drag force D acts opposite to a direction of W and lift force L acts perpendicular to W. Thrust force T is generated as a component of a resultant force R consisting of L and D to the advancing direction. With the above variables, geometrical relations are established with a velocity triangle composed of U, V, W and slip angle β. Furthermore, thrust force T must be equal to parasite drag of the body, D_B in a trimmed state. The following equations were derived according to the above relations. Thrust T, power P and efficiency η can be defined with them and be normalized:

$$T = \frac{1}{2}\rho W^2 S C_R \cos(\gamma + \alpha - \theta) = \frac{1}{2}\rho W^2 S C_T \tag{1}$$

$$P = \frac{1}{2}\rho W^2 U S C_R \cos(\gamma - \beta) = \frac{1}{2}\rho W^3 S C_P \tag{2}$$

$$\begin{aligned}\eta &= TV/P \\ &= \cos(\gamma + \alpha - \theta)/\{(U/V)\cos(\gamma - \beta)\}\end{aligned} \tag{3}$$

where

$$L = \frac{1}{2}\rho W^2 S C_L, \quad D = \frac{1}{2}\rho W^2 S C_D \tag{4a, b}$$

$$C_R = \sqrt{C_L{}^2 + C_D{}^2} \tag{4c}$$

$$\gamma = \tan^{-1}(L/D) \tag{5}$$

In the above variables, the following geometrical relations are established with the velocity triangle composed of U, V and W:

$$W/V = (U/V)\cos\beta - \sqrt{1 - (U/V)^2 \sin^2\beta} \tag{6}$$

$$\begin{aligned}&\tan(\theta - \alpha) \\ &\quad = (U/V)\sin\beta / \{(U/V)\cos\beta - (W/V)\}\end{aligned} \tag{7}$$

$$\delta = \theta - (\alpha + \beta) \tag{8}$$

Eqs. (6) and (7) are reduced to the following equation:

$$\beta = \sin^{-1}\{\sin(\theta - \alpha)/(U/V)\} \tag{9}$$

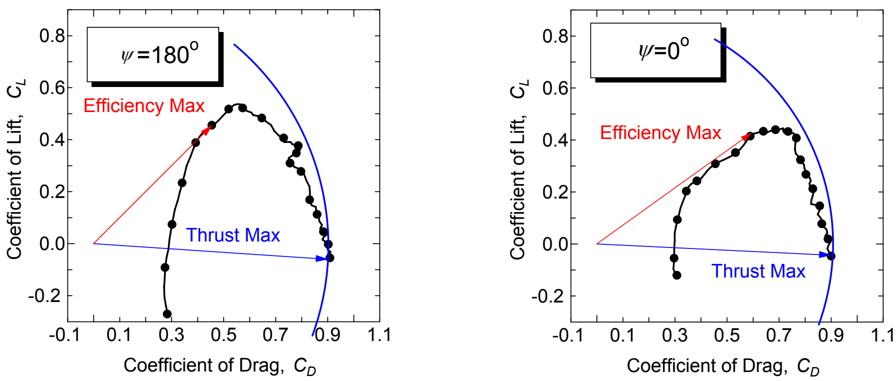
In a trimmed state, thrust force T must be equal to parasite drag of the body, D_B

$$T = 1/2\rho W^2 S C_T = D_B = 1/2\rho V^2 S_B D_P \tag{10}$$

where S_B is a drag area of the driven body.

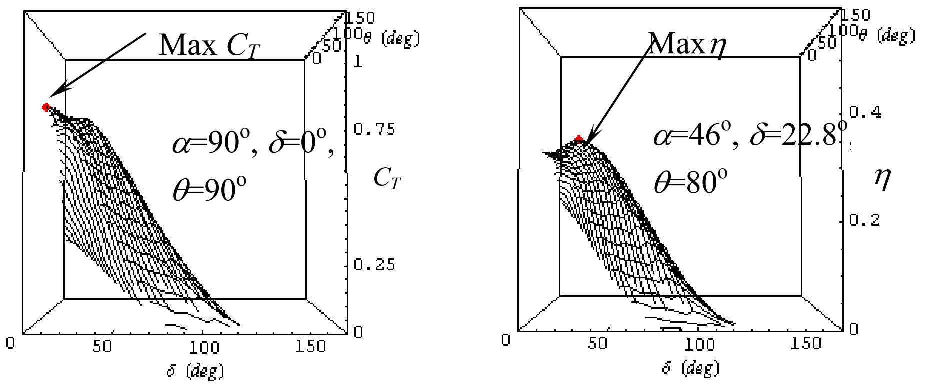
RESULTS AND DISCUSSION

Figs. 4(a) and (b) are polar curves based on two different sweepback angles, ψ= 180°and 0° respectively, showing the relationship between the lift coefficient C_L and the drag coefficient C_D. The polar curves also correspond to a change of angle of attack α from 0° to 90° every 1°. Markers are shown every 5 degrees in angle of attack α in the



(a) ψ=180°: Catch & Downsweep (b) ψ=0° : Pull (Upsweep)

Fig. 4 Polar curves at different sweepback angle, ψ=180°, 0°.
Each graph shows the maximal efficiency point and the maximal thrust point.



(a) Thrust coefficient C_T, based on driving angle δ and tilt angle θ.

(b) Thrust efficiency η, based on driving angle δ and tilt angle θ.

Fig. 5 Calculated results of a hand palm specification at ψ=0° Pull.

respective curves. An arc of C_{R0} is drawn from the point where the maximal thrust force occurs at angle of attack α=90°. The calculated thrust coefficient C_T at ψ= 0° obtained from the polar curves is shown in Fig.5 (a). The maximum thrust point exists for the thrust coefficient, and the point is corresponding to the farthest point of drag from the origin of the polar curve, that is, the maximum resultant force point in Figs. 4. During the phase from catch to upsweep, the state angle at the maximum thrust point was turned out that tilt angle θ, angle of attack α and driving angle δ of a hand palm were 90°, 90° and 0° respectively. In this state, the style of swimming produced the maximum thrust in a drag type. Thrust efficiency was similarly obtained by the calculations based on the experiment. The calculation results are shown in Fig.5 (b). The maximum point of the thrust efficiency exists, and the point agrees with the tangential point from the origin to the polar curve in Figs. 4. Figure 6 summarizes the parameter of each posture angle of the hand palm in each mode. For the maximum thrust mode shown by the dotted line, the tilt angle shows 90° in Catch and Pull phase except Finish phase. The driving angle also shows 0° in Catch and Pull phase except Finish phase. That is, it is meant that the hand palm located squarely to the driving direction should drive straight parallel to the traveling direction of the body. Figure 7 indicate the stroke path of the hand palm in the maximum thrust mode from the absolute

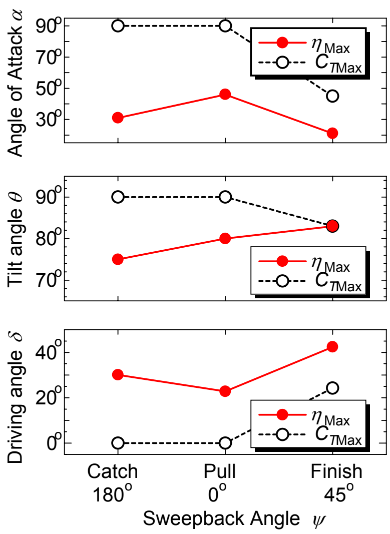


Fig. 6 Transition of posture angle of the hand in each phase in the maximum thrust mode and the maximum.

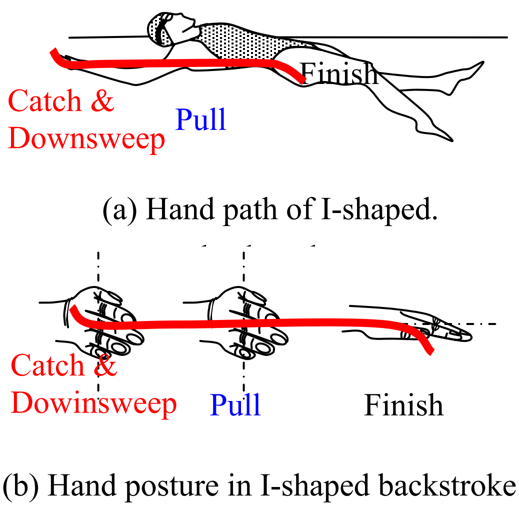


Fig. 7 Side view of proposed I-shaped back stroke.

coordinate system. The author named it as I- shaped pull stroke. For the maximum efficiency mode shown in the solid line, the tilt angles indicate that hand palm inclines less than vertical. The driving angle shows that hand palm drives diagonally from 30 to 45 degrees to the traveling direction or to the surface of the water. Considering the sweepback angle and the driving angle, the movement of the hand palm becomes S-shaped pull swimming shown in Fig. 1. The downward sweep operation is inevitable because of rolling in the finish phase of each stroke.

CONCLUSION

The thrust force and the thrust efficiency were calculated in the backstroke using the experimental data, and it was found that the optimal arm strokes exist for the maximum thrust swimming and the maximum efficient swimming as follows:

1) The swim of the maximum thrust in the backstroke was a swim of the drag type: I-shaped pull, straight pull back.
2) The swim of the maximum efficiency in the backstroke was a swim of the lift-drag type: S-shaped pull.

REFERENCES

Berger, M.A.M., Groot, G. de & Hollander, A.P. (1995). Hydrodynamic drag and lift forces on human hand/arm models. Journal of Biomechanics, 28, 125-133.

Counsilman, J.E. (1968). Science of Swimming. Prentice-Hall, Englewood Cliffs, N.J.

Hollander, A. P., de and van Ingen Schenau, G. J., (1987) Contribution of the legs to propulsion in front crawl swimming, Swimming Science V, pp.17-29. Human Kinetics Publishers, Champaign, IL.

Ito, S. and Okuno, K. (2003). A FLUID DYNAMICAL CONSIDERATION FOR ARMSTROKE IN SWIMMING, Biomechanics and Medicine in Swimming IX, pp.39-44, Pub. de l'univ. de Saint-Etienne.

Sanders, R.H. (1997). Extending the "Schleihauf" model for estimating forces produced by a swimmers hand. In B.O. Eriksson and L. Gullstrand Proceedings of the XII FINA World Congress on Sports Medicine. Goteborg, Sweden 12-15 April 1997, pp.421-428.

Schleihauf, R.E. (1979). A hydrodynamic analysis of swimming propulsion, Swimming III, pp70-109, University Park Press, Baltimore.

Relationship between the kinematical parameters in the propulsive phase and the sprint performance in front crawl swimming.

Hiroshi ICHIKAWA[1], Takahisa SHIRAKI[2] and Takeo NOMURA[2]
[1] Japan Institute of Sports Sciences, Department of Sports Information, Japan
[2] University of Tsukuba, Graduate School of Comprehensive Human Sciences, Japan

The purpose of this study was to investigate the relationship between the kinematical parameters and the sprint ability in front crawl swimming. The subjects were nine well-trained male swimmers. They performed front crawl swimming with five different velocities (1.1-1.9 m/s) in swimming flume. The hand trajectory was obtained by three dimensional motion analysis. The propulsive phase was defined as the duration to push water backward. It was observed that there was a significant correlation between the relative propulsive duration in the trial 1.7 m/s and the best record of 50 m freestyle ($r = -0.67$, $p < .05$). The relative propulsive duration would have a possibility to be one of the parameters to evaluate the sprint ability in front crawl swimming, although it was difficult to discuss the swimming propulsion using only the kinematical parameter.

Key words: *kinematical parameter, propulsive phase, front crawl swimming*

INTRODUCTION

It would be needed to measure the hydrodynamic force exerted by swimmer to evaluate the swimming technique and performance dynamically. As a methodology to quantify the hydrodynamic force in swimming, there were the calculation/simulation by CFD (Bixler *et al*. 2002) and SWAM (Nakashima 2006), the measurement by PIV-method (Matsuuchi *et al*. 2006, Miwa *et al*. 2006) and using pressure sensor (Takagi *et al*. 2002). However, these would be developing to evaluate the swimming technique and performance in the training field.

It would be easier to obtain the kinematical parameter than the hydrodynamic parameter. Stroke rate, stroke length and index of coordination are major kinematical parameters of swimming. The stroke rate and length were well-known as the parameters to explain swimming velocity directly. The index of coordination was suggested by Chollet et al. (2000), and then it has been discussed the relationship with the swimming performance. In the definition of the index of coordination, the phase of arm motion in front crawl swimming were separated into propulsive and non-propulsive phases. The concept seems to be interesting to discuss the relationship between the kinematical data and the swimming performance.

In this study, focused the propulsive phase of the arm stroke in front crawl swimming, the purpose was to investigate the relationship between the kinematical parameters during propulsive phase and the sprint performance.

METHODS

The subjects, who were nine well-trained male swimmers (age: 20.1±1.0 yrs, height: 1.80±0.06m, weight: 71.1±4.8kg, best record of 50 m freestyle: 24.59±0.65 sec), performed front crawl swimming with 1.1, 1.3, 1.5, 1.7 and 1.9 m/s in swimming flume (Igarashi Inc, length: 5 m, width: 2 m, depth: 1.3 m, range of velocity: 0 - 2.5 m/s). The swimming motion was recorded by four cameras (TC-C1381, Victor Inc.), which were synchronized the time code registration with 60Hz.

The displacements of left fingertip, wrist, elbow, shoulder and right shoulder of the subjects were digitized and transformed into three-dimensional coordinates with DLT-method using the software for motion analysis (Frame-Dias II, DKH Inc.). Each coordinates were smoothed by IIR digital filter with the cutting-off frequency 5Hz.

The middle point of the fingertip and the wrist was calculated as the displacement of the hand. The coordinates were transformed from a global coordinate system with the swimming flume to the moving coordinate system based on water. The propulsive phase was defined as the duration which swimmer's hand moved backward based on the water (Figure 1).

The duration of the propulsive phase were calculated in each trial to investigate the relationship with the best record of 50 m freestyle as the sprint ability. The moving distance and the velocity of swimmer's hand in propulsive phase were also calculated in a similar way.

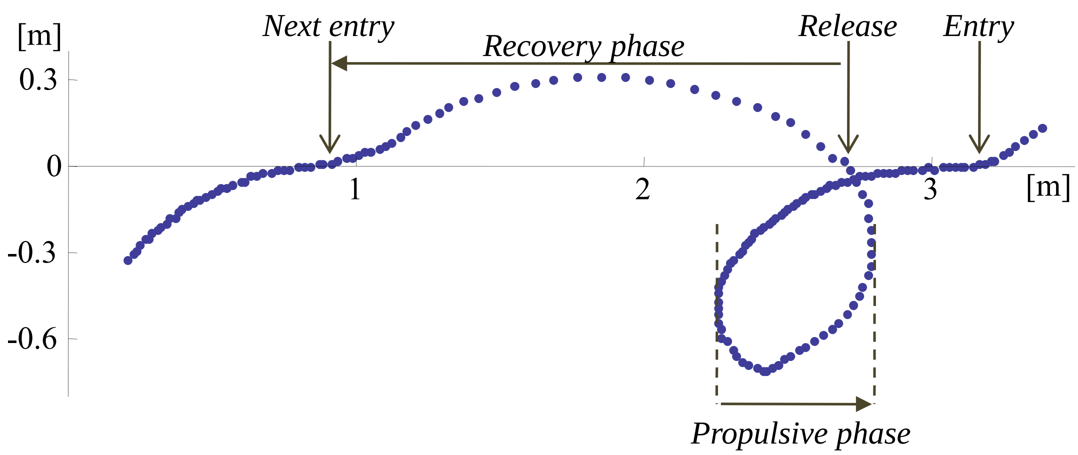


Figure 1. The hand trajectory on sagittal plane in front crawl swimming, and the definition of phases based on the hand trajectory.

RESULTS

Figure 2 shows the stroke time (t_{stroke}), the duration of propulsive phase (t_{prop}) and the relative propulsive duration, which was defined as the ratio between the duration in propulsive phase and one stroke time (relative-t_{prop} = t_{prop} / t_{stroke}). The stroke time and the propulsive duration decreased with the increment of the swimming velocity, while the relative propulsive duration increased.

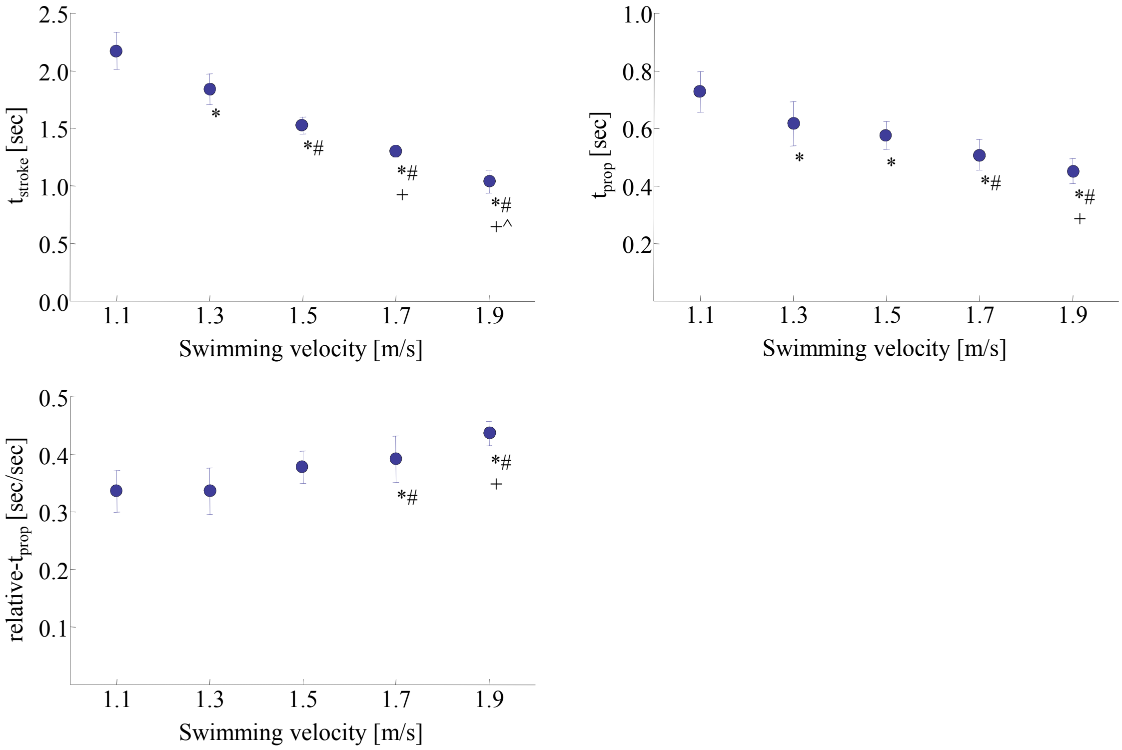


Figure 2 Comparisons between the trials of stroke time (upper left graphic), propulsive duration (upper right) and relative propulsive duration (lower left) of all subjects (n=9). The marks *, #, + and ^ show significant difference compared with 1.1 m/s, 1.3 m/s, 1.5 m/s and 1.7 m/s, respectively. The level of significance is 5%.

The propulsive duration had no significant correlation with the best record of 50 m freestyle in all trials. In 1.7 m/s trial, the relative propulsive duration had a significant correlation with the best record of 50 m freestyle ($r = -0.67$, $p < .05$, Figure 3), while there were no significant correlation in the other trials (Table 1).

The distance, which the hand moved backward along the swimming direction in propulsive phase (d_{prop}), had no significant correlation with the sprint performance in all trials. Also, the mean velocity of the hand during propulsive phase (mean-v_{prop}) had no significant correlation with the sprint performance (Table 1).

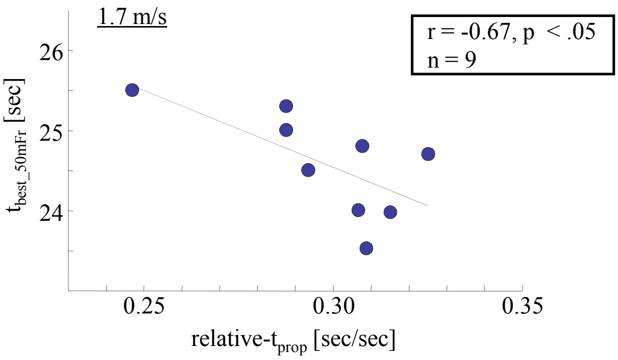


Figure 3 Relationship between the relative propulsive duration of the trial 1.7 m/s and the best record of 50 m Freestyle ($r = -0.67$, $p < 0.05$).

Table 1 Correlation coefficient of each parameter with the best record of the 50 m freestyle.

	1.1 m/s	1.3 m/s	1.5 m/s	1.7 m/s	1.9 m/s
t_{stroke}	0.354	0.347	-0.017	0.454	0.035
t_{prop}	-0.166	-0.220	-0.464	-0.470	-0.498
relative- t_{prop}	-0.381	-0.529	-0.347	-0.670*	-0.323
d_{prop}	-0.202	-0.304	-0.289	-0.048	-0.220
mean-v_{prop}	-0.104	-0.054	0.157	0.345	0.178

*: $p < .05$

DISCUSSION

The relative propulsive duration (relative-t_{prop}) increased with the increment of the swimming velocity, while the propulsive duration (t_{prop}) decreased because the stroke time (t_{stroke}) decreased (Figure 2). The swimming velocity in intra-individual variation would be controlled by not only the stroke rate (= 1/ t_{stroke}) but also the relative propulsive/non-propulsive duration.

It was discussed whether it was possible to evaluate the sprint ability by the kinematical parameters in the propulsive phase in freestyle swimming. The duration of the propulsive phase had possibilities to be one of the parameters to evaluate the swimming performance (Figure 3), because it would be in propulsive phase that the propulsive force was exerted by the arm stroke. In this study, there was no significant correlation between the best record of 50 m freestyle and the relative propulsive duration in the trials except for the trial 1.7 m/s, as the relative propulsive duration would depend on the swimming velocity. It could be not appropriate to evaluate the sprint ability using the parameter in the lower velocity. The stroke length decreased in 1.9 m/s to the other trials significantly (Figure 4). So the relative propulsive duration in the trial 1.9 m/s have no significant correlation with the record of 50 m freestyle, because it would be too fast to execute their proper performance. It was supposed that better swimmers had the stroke technique to be more propulsive and less non-propulsive duration, and it would be more difficult to execute the technique in faster swimming.

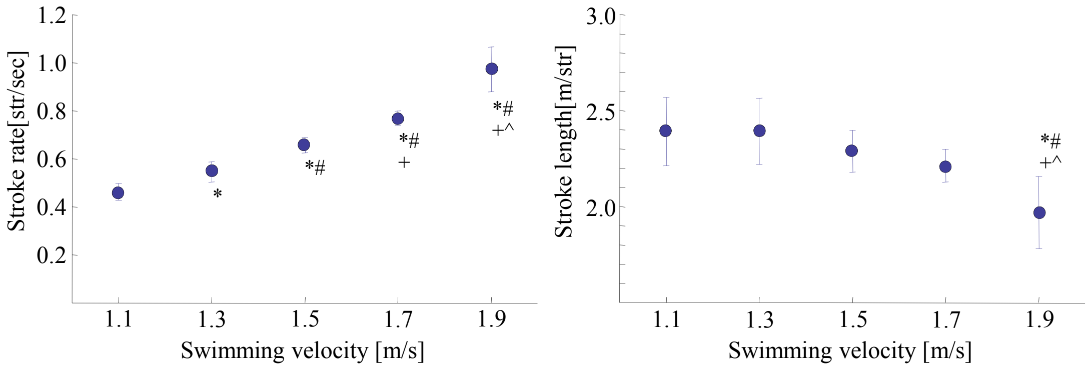


Figure 4. Comparisons between the swimming velocities of stroke rate (left) and stroke length (right) of all subjects (n=9). The marks *, #, + and ^ show significant difference compared with 1.1 m/s, 1.3 m/s, 1.5 m/s and 1.7 m/s, respectively. The level of significance is 5%.

The distance to push water backward and the mean velocity of the hand in the propulsive phase (d_{prop} and mean-v_{prop}) had no significant correlation with the record of 50 m freestyle (Table 1). That is because the other factors, such as the propulsion by legs and the drag of whole body, would contribute more to the sprint ability. Furthermore, it was supposed that the propulsion by arms would depend on not only pushing water backward in the propulsive phase.

It was suggested that it would be difficult to discuss the propulsion using only the kinematical parameter. It is expected that the future methodology will be developed to measure the propulsion and to evaluate the swimming technique.

CONCLUSION

Measured the trajectory of swimmer’s hand by three dimensional motion analysis, it was investigated that the relationship between the kinematical parameters during the propulsive phase and the sprint ability in front crawl swimming. It was concluded that the relative propulsive duration would have the possibility to be one of the parameters to evaluate the sprint ability, although it was difficult to discuss the propulsion using only the kinematical parameter.

REFERENCES

1. Bixler B., Riewald S. (2002) Analysis of a swimmer's hand and arm in steady flow conditions using computational fluid dynamics. Journal of Biomechanics, 35,

pp.713-717
2. Chollet D., Chalies S., Chatard J.C. (2000) A new index of coordination for the crawl: description and usefulness. International Journal of Sports Medicine, 21(1), pp.54-59
3. Matsuuchi K., Hashizume T., Nakazawa Y., Nomura T., Shintani H., Miwa T. (2006) Flow visualization of unsteady flow field around a monofin using PIV. Biomechanics and Medicine in Swimming X. Portuguese Journal of Sport Sciences (eds.) Vilas-Boas, J.P., Alves, F. and Marques, A., pp.60-62
4. Miwa T., Matsuuchi K., Shintani H., Kamata E., Nomura T. (2006) Unsteady flow measurement of dolphin kicking wake in sagittal plane using 2C-PIV. Biomechanics and Medicine in Swimming X. Portuguese Journal of Sport Sciences (eds.) Vilas-Boas, J.P., Alves, F. and Marques, A., pp.64-66
5. Nakashima M. (2006) “SWUM” and “SWUMSUIT” – a modeling technique of a self-propelled swimmer. Biomechanics and Medicine in Swimming X. Portuguese Journal of Sport Sciences (eds.) Vilas-Boas, J.P., Alves, F. and Marques, A., pp.66-68
6. Takagi, H., Sanders, R. (2002) Measurement of propulsion by the hand during competitive swimming. The Engineering of Sport 4. (eds.) Ujihashi, S. Haake, S. J., pp.631-637

Effect of take-off angle on start performance in swim-start

Tsuyoshi Takeda[1], Hiroshi Ichikawa[2], Shozo Tsubakimoto[3], Takeo Nomura[3]

[1] University of Tsukuba, graduate school of comprehensive human sciences, Tsukuba city, Japan

[2] Japan Institute of Sports Sciences, Japan

[3] University of Tsukuba, Institute of Health and Sport Sciences, Japan

The purpose of this study was to clarify the effect of the take-off angle change on the take-off velocity, flight distance and time on the starting block, and suggest the appropriate take-off angle range for the start performance until water entry. Twelve well trained male swimmer participated as a subject in this study. Each subject performed the grab start from the starting block with the three different take-off angles (Higher: HT, Normal: NT, Lower: LT). Kinematic variables were calculated by 2D motion analysis using the DLT method. There was significant correlation between the body angle at the take-off and the take-off velocity. The decrement of take-off angle resulted in the significant increment of take-off velocity, significant decrement of flight distance, and no significant difference of block time. Proper take-off angle range for the start performance until water entry was from 11.8deg to -18.7deg.

Key words: *Grab start, Start phase, Kinematics*

INTRODUCTION

The structure of competitive swimming race was divided into the start phase, stroke phase, turn phase and finish phase. In the start phase, A swimmer can generate higher velocity by pushing off from the starting block or the wall in the pool than swimming velocity in the other phases. It was important to minimize deceleration from maximum velocity of the start phase and transfer to stroke phase for success of the race.

The trajectory of center of gravity (CG) of swimmer after the take-off from the starting block was affected by gravity and describe a parabola because air resistance was small. The magnitude and direction of initial velocity vector at the take-off (take-off velocity and take-off angle, respectively) determined the movement of swimmer during aerial phase; these two parameter were determined horizontal take-off velocity, flight distance, the magnitude and direction of the velocity vector at the water entry. The importance of magnitude of initial velocity vector is well known. However, the optimal direction of the velocity vector for the swimming performance has not been investigated. Numerous study about a swim-start had investigated the difference between the grab start and track start (1,2).

The purpose of this study was to clarify the effects of take-off angle change on take-off velocity, flight distance and duration time on the starting block, and suggest the appropriate take-off angle range for start performance until water entry.

METHODS

Subject

Twelve well trained male swimmers participated as a subject in this study. They had performed the grab start usually in the competition. Their physical characteristics (mean ± SD) were: height 178.2 ±5.8 cm, body weight 71.5 ±5.7 kg, age 21.0 ± 1.2 yrs. All participants were provided the informed consent.

Experimental settings

The experiment was carried out in the indoor swimming pool. The starting movement were recorded by a high-camera (FAST-CAM PCI, Photron, Inc., JAPAN) with 1/250 second of the shutter speed and 250 frame per second, and the 2D-DLT method was used for calculating the 2D coordinates of subjects. Markers were placed on the right side of each subject at the shoulder, hip, knee, ankle, heel, elbow, wrist, metacarpophalangeal joint, top of head, ear and toe for the identification of body segments on the video monitor.

Trials

Each subject performed the grab start from the starting block with the three different take-off angles: 1)NT: grab start with usual take-off angle; 2)HT: grab start with higher take-off angle than NT; 3)LT: grab start with lower take-off angle than NT. All subject had practiced the experimental trials (HT, NT, LT) for seven days before the experiment in order to be able to change the take-off angle.

Data analysis

The coordinate data was digitally filtered using the low-pass Butterworth filter at 6Hz. The definition of kinematical variables is given below;

Take-off velocity [m/s] (*V*): the magnitude of velocity vector of CG of swimmer at the take-off.

Take-off angle [deg] (ϕ): the angle between horizontal line and take-off velocity vector.

Body angle [deg] (θ): the angle between horizontal line and the line from CG to the edge of starting block.

Block time [sec]: the time required from starting signal to the take-off.

Flight distance [m] : the horizontal distance from the cross point between the wall and water surface line to CG of swimmer at the water entry.

Entry angle [deg] (α): the angle between horizontal line and velocity vector at water entry of CG.

These definitions were shown Figure 1.

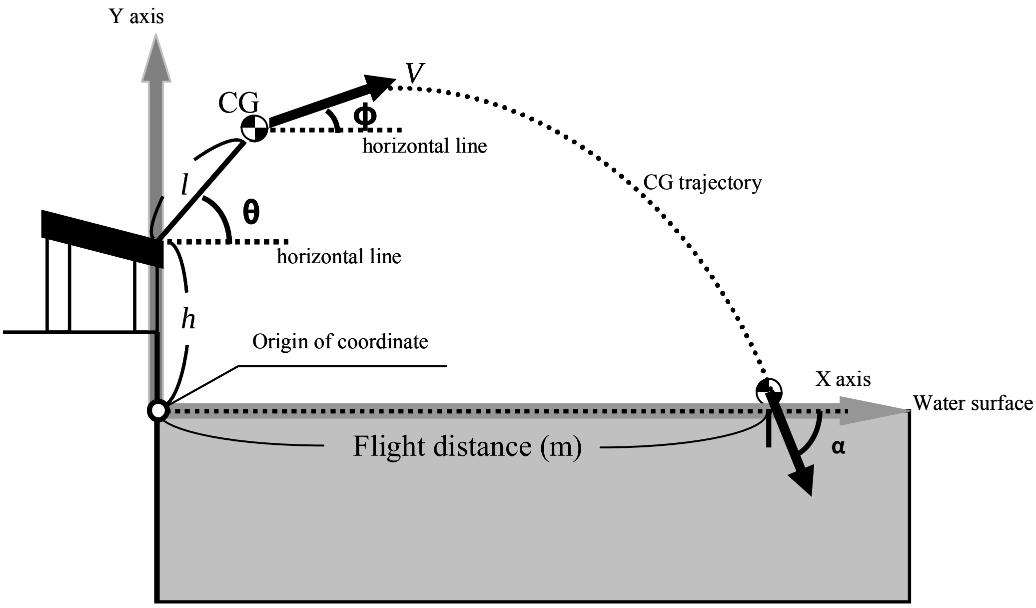


Figure 1 Schematic view of definitions of kinematic variables at present study.
V: Take-off velocity [m/s], θ: Body angle [deg], ϕ: Take-off angle [deg], *l*: Line from starting block edge to swimmer's CG (center of gravity) *h*: Height from water surface to starting block edge. α : Entry angle [deg]

We simulated CG trajectories (x, y) using the equations of projection (e-1),(e-2), and the liner regression equations of body angle at the take-off and take-off angle (e-3), body angle at the take-off and take-off velocity (e-4) using the results of present study.

$$x = V\cos\phi \cdot t + l\cos\theta \quad \text{(e-1)}$$

$$y = V\sin\phi \cdot t - \frac{1}{2}gt + l\sin\theta + h \quad \text{(e-2)}$$

where g is gravity acceleration, t is the time after take-off, l is the distance between the starting block edge and CG.

Statistical analysis

Comparisons of the kinematical variables were performed a one-way analysis of variance among each trial. Post hoc multiple comparisons were made by using Tukey's test. The relations of the body angle at the take-off and take-off angle, the take-off angle and take-off velocity was investigated by the Pearson's correlation coefficient test at each trial. The level of significance was set at $P < 0.05$ for all analyses.

RESULTS AND DISCUSSION

Table 1 shows mean and standard deviations of kinematical variable in each trial.

Table 1 Kinematical variables in each trial (HT , NT and LT) Values were indicated mean± standard deviations.

		HT		NT		LT		Significant difference		
		Mean	SD	Mean	SD	Mean	SD	HT-NT	NT-LT	HT-LT
Take-off angle	[deg]	6.6 ±	5.8	-2.3 ±	4.6	-12.2 ±	5.3	**	**	**
Body angle at the take-off	[deg]	33.1 ±	5.0	25.0 ±	3.8	15.6 ±	4.7	**	**	**
Take-off velocity	[m/s]	4.01 ±	0.23	4.30 ±	0.18	4.56 ±	0.13	**	**	**
Horizontal take-off velocity	[m/s]	3.96 ±	0.26	4.28 ±	0.17	4.44 ±	0.13	**	*	**
Flight distance	[m]	3.30 ±	0.16	3.15 ±	0.20	2.80 ±	0.26		**	**
Block time	[sec]	0.806 ±	0.061	0.804 ±	0.038	0.855 ±	0.067			

* : significant difference at $p < 0.05$.

** : significant difference at $p < 0.01$.

There were significant differences among trials in the take-off angle, the body angle at the take-off, the take-off velocity and the horizontal take-off velocity. For the flight distance, there were significant differences between NT and LT, HT and LT. No significant difference existed among trials in the block time. The take-off angle, the body angle at the take-off and the flight distance significantly decreased in order of HT-NT-LT. The take-off velocity (resultant velocity) and the horizontal take-off velocity significantly increased in order of HT-NT-LT.

Significant change of the take-off angle means that the participants could change the take-off angles of the experimental trials (HT, NT and LT) according to the purpose of this study.

The increment of the take-off velocity with decrement of the take-off angle (HT-NT-LT) was caused by gravity. Swimmer has to generate vertical reaction force against gravity in order to increase the take-off angle. Therefore, swimmer could generate higher take-off velocity when swimmer took off at lower take-off angle. Figure 2 shows relationship between the take-off angle and the take-off velocity.

Figure 3 shows relationship between the body angle at the take-off and the take-off angle. Significant correlation ($P<0.01$) existed between the both angles in each trial (HT: $r = 0.93$, NT: $r = 0.93$, LT: $r = 0.94$). These correlations indicated that the take-off angle was related to the forward inclination of whole body, and the position of center of gravity at the take-off changed according to the take-off angle.

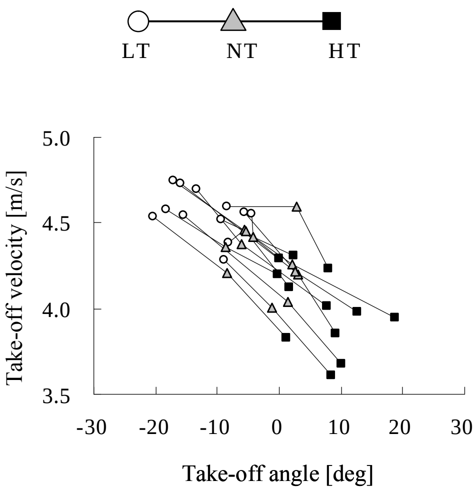


Figure 2 Relationship between the take-off angle and take-off velocity. The line are drawn between each trial of the same subject.

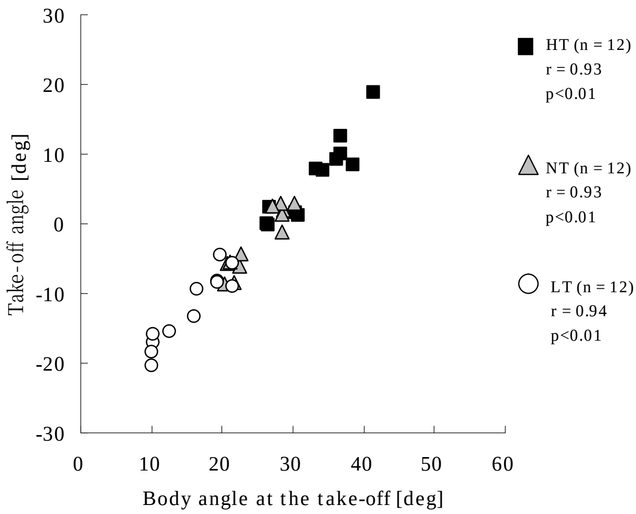


Figure 3 Relationship between the body angle at the take-off and take-off angle. Liner regression equation of all trials was $\phi=1.0711\theta-28.94$ (e-3).

Figure 4 shows changing in the flight distance, horizontal velocity and entry angle with changing in the take-off velocity and body angle at the take-off from the calculation using the equations (e-1, e-2, e-3, e-4). The liner regression equation of the body angle at the take-off and take-off velocity was $V= -0.028\theta + 5.0211$ (e-4).

In the calculation of these equations (e-1, e-2, e-3, e-4), when the flight distance became maximum (3.36m) the take-off angle was 11.8 deg, when the horizontal take-off velocity became maximum (4.49m/s) it was -18.7 deg, when the entry angle became the shallowest (-44.7deg) it was -22.5 deg. The effect of entry angle on start performance has not been investigated. Consequently, these calculation suggested that the proper take-off angle for start performance until water entry existed within from 11.8deg to -18.7deg.

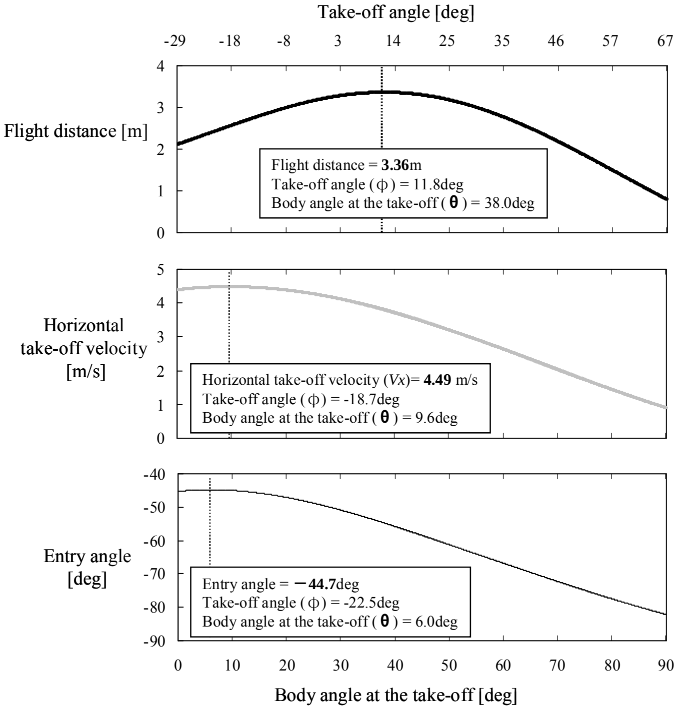


Figure 4 The flight distance, horizontal take-off velocity and entry angle related to the body angle at the take-off and take-off angle in the calculation using e-1, e-2, e-3 and e-4.

CONCLUSION

The purpose of this study was to clarify the effects of take-off angle change on the take-off velocity, flight distance and time on the starting block, and suggest the appropriate take-off angle range for start performance until water entry. The decrement of take-off angle resulted in significant increment of the take-off velocity, significant decrement of the flight distance, and no significant difference of the block time. The proper take-off angle range for the start performance until water entry was from 11.8deg to -18.7deg.

REFFERENCES

1. Counsilman J.E, Counsilman B.E., Nomura T., and Endo M. (1988). Three types of grab starts for competitive swimming. International Series on Sport Sciences, 18 SWIMMING V：81-91.
2. Zatsiorsky, V.M., Bulgakova, N.Z., Chaplinsky N.M. (1979). Biomechanical analysis of starting techniques in swimming. International Series on Sport Science, 8 SWIMMING Ⅲ, Terauds J. and Bedingfield. EW.：199-206.

The effect of cognitive intervention on stroke distance in age-group swimmers

Anna C Schmidt[1], Bodo E Ungerechts[2]

[1] University of Göttingen, Department of Society and Training, Germany

[2] University of Bielefeld, Department of Neurocognition an Action – Biomechanics, Germany

Advanced age-group swimmers and their coaches try to optimize their individual swimming technique. Therefore the stroke distance is often mentioned as a criteria. If swimmers cover more distance stroke by stroke, their movements under water are more efficient. The base of a successful motion sequence is a well-structured mental representation. Mental representation can be visualized by using special software. Based on these results, special workouts have been designed. During a six-week training period the participating group worked precisely according the advised concept. As pre-and post-tests the swimmers worked on the computer and performed 25 meters freestyle starting in the water, as fast as they could. On the date of the post-test the swimmers had a mental representation that was more organized and made improvements in their swimming performance. The distance was covered at nearly same speed, but with a lesser stroke rate; the stroke distance therefore increased.

Key words: *front crawl, cognitive intervention, mental representation, stroke parameters*

INTRODUCTION

Highly skilled swimmers cover as much distance per stroke as possible in an aquatic space. Therefore the stroke distance is often mentioned as a criteria for a good swimming technique (Dekerle et al. 2005, Sanders 1999, Arellano et al. 1994, Reischle 1988). An improved technical swimming performance results, among other things, in a longer stroke distance. The athlete is able to swim the same race-distance with the same or even a lesser stroke rate and probably in less time. In case of less time and increased stroke distance the so-called stroke-index (speed squared and multiplied by stroke distance) will increase as well. RUDOLPH (2001) showed elite swimmers like Popov or de Bruijn, to reach their fastest swimming times by longer stroke distance and less stroke rates, with a higher stroke-index throughout.

Tab.1: Comparison of the performance of 50 meters freestyle of Alexander Popov (Olympic Games 1996 and 2000) (RUDOLPH 2001)

	Time 50m [s]	**Speed [m/s]**	**Stroke rate [1/min]**	**Stroke distance [m]**	**Stroke-Index [m^3/s^2]**
Olympics 96	22.13	2.13	52.4	2.44	11.07
Olympics 00	22.24	2,13	58.2	2.19	9.94

To gain more effective underwater-movement, swimmers could improve their power (without technical training this might be limited) and / or try to optimize their motion sequence in and with water. In contrast to most other sports, swimmers do not have a fixed base to push off. Instead, they produce propulsion due to an interaction of the body and the water-mass. Therefore it is very important to teach swimmers how to work with water properly while executing regular strokes. To achieve this, emphasis should be put on how stroking is mentally represented in swimmers, even age-group swimmers. Coaches always look for possibilities on how to improve the action associated with thrust production of each swimmer. In this context a cognitive intervention which is based on the structural dimensional analysismotoric (SDA-M)[1] according to SCHACK (2003) can be used. This method describes mental representation structures and enables statements about the cognitive architecture of complex movements in the long-term memory. So the main reason for problems of (stroking) actions can be localized in a way, which fits the demand of effective communication between coach and athlete.
The purpose of this paper is the report about the effect of mental-representation-research based intervention on the stroking ability of age-group swimmers.

METHOD

22 age-group swimmers preparing for their first participation in national championships took part in the intervention. On the appointed days they performed two X 25m crawl at full speed with water start. In doing so the data of the two trials were averaged. During these sprints a) the time over 10m distance – from 10 to 20 m – and b) the stroke rate

[1] Ungerechts/Schack (2006) did a first research about the representation of butterfly-swimmers using SDA-M. They also described the used method.

were measured. Finally the stroke distance and the stroke index were calculated.

Fig. 1 Surface of the Split-Program (ENGEL/SCHACK 2001)

The intervention consisted of using the following -a) appropriate software “Split” (SCHACK et al. 2000) used to sort out “basic action concepts”, called nodes, representing arm/hand actions during crawl stroke and b) individualized stroking instructions over a six week period. The nodes were established by the coach based on his usual stroking instructions, but in a more structured manner.

After sorting out all nodes according to the criteria, whether they belong to the anchor node or not, one gets an impression of the mental representation, which the swimmer has of his motion sequence (in this example of the crawl arm stroke). Using this so-called split-technique, “Split” calculates distances between the nodes, which is the basis for further data analysis. As a result of factor analysis one obtains a factor matrix, classified by clusters. These results can be demonstrated by a so-called dendrogram (Schack et al. 2006, Schack/Lander 1988). By analyzing the dendrograms and the clusters and after communicating with the coach special training-programs (theoretical and practical ones) had been worked out, to be done or to be followed for the six week training period. So the individual stroking instructions were inferred from the results of the SDA-M tests.

The two dendrograms below show the results of an age-group swimmer belonging to the intervention group. The first one points out the result of Split at the pre-test, the second one the result of the test after the six week training period. There are changes in the mental representation. Initially, the swimmer does not have a structured representation or a good idea of the crawl arm stroke and its nodes. But after the training period he shows a well-organized structure of the motion sequence. There are three clusters with the main phases of the movement: the part above the waterline with breathing and forward hand movement, the first phase of the underwater movement (entry to the end of forward-downward phase) and the main impulse phase (pronation to slicing of the hand).

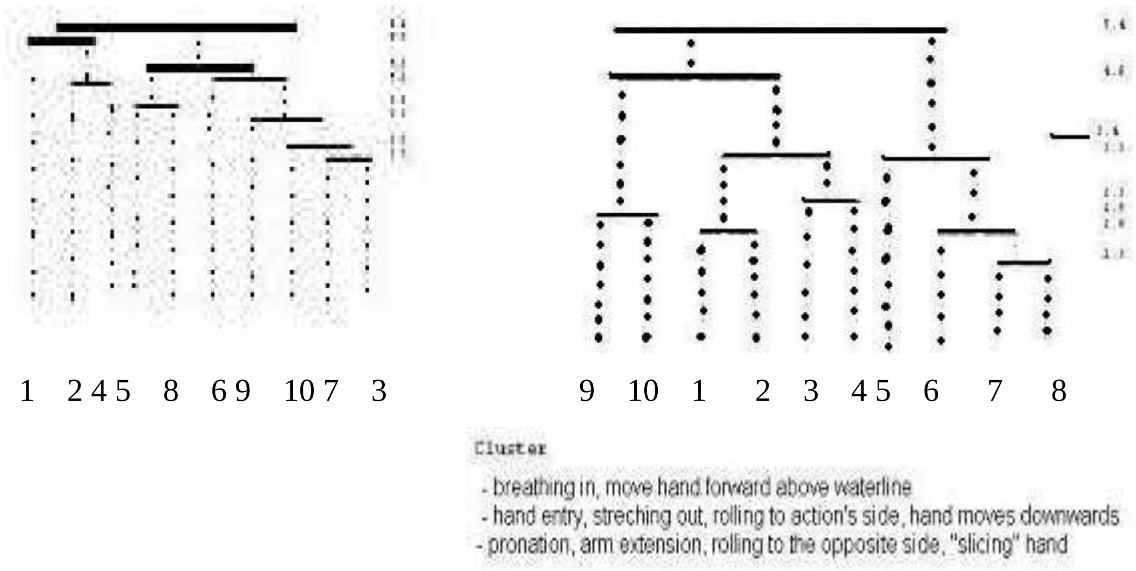


Fig. 2 The dendrogram on the left visualise the mental representation of the swimmer (without any cluster and without a real regularity). On the right is the dendrogram of the same swimmer after the six week training period – with cluster and regularity of nodes

RESULTS

The improvement of the mental representation shown in the example above also led to improvements in the swimming parameters. As a criteria for technical progress, which is a more efficient motion sequence, the stroke distance in first and the stroke index in second place has been chosen, because this combines stroke distance and swimming speed[2].

The following schedule show the corresponding data of Test I and Test II for the whole group. Apart from stroke rate and stroke index, speed and stroke rate are also shown as important parameters for the performance of the swimmer (and dependent parameters).

---

[2] Stroke distance and stroke rate are not independent of each other (cf. Sanders 1999). For an improvement of stroke distance the stroke rate must not decline too much, because then the speed will also decline also and the swimming performance in competition will be worse than before.

Tab. 1 Statistical data for group

Parameter	Test 1 (mean, std)	Test 2 (mean, std)
Speed m/s	1,52 ± 0.09	1,51 ± 0.11
Stroke rate 1 /min	49,64 ± 4,4	47,88 ± 3,43
Stroke distance m	1,85 ± 0,16	1,90 ± 0,19
Stroke index	4,33 ± 0,70	4,39 ± 1,01

Comparing the results of stroke distance, there is an increase of approximately 0.05 meters. So if a swimmer for instance does 60 strokes, in Test II he would advance 3 meters more than in Test I. The speed stays nearly at the same level. It slowed down only 0.01 meters per second. The stroke rate decreases by nearly 2 strokes per minute. Due to the stroke distance the stroke index increases by 0.06.

The following diagram shows the changes from Test 1 to Test 2, as an effect of the special intervention during the six week training period. The stroke distance of Test 1 and Test 2 are copied, including the shortest and the longest shown distance. Furthermore 25%, 50% (median) and 75% per cent are described as well as the mean of all the stroke distances. On the left the results of the pre-test are shown, on the right there are the results of the post-test.

The mean variation is bigger for the Test 2, the longest distance increased and the shortest distance declined, although the mean and the median increased. In Test 1 the mean and median were nearly at the same level, while in the Test 2 the median increases considerably. The mean increases as shown in the tables above. There is a 75 per cent increase, and a 25 per cent decline, so there is an overall improvement after the six week training period, although it is not statistically significant. Analogue to the stroke distance are the changes in stroke index, because of the nearly same speed: The mean variation is bigger for the Test 2I, the highest stroke index increased and the lowest declined, although the mean and the median increased.

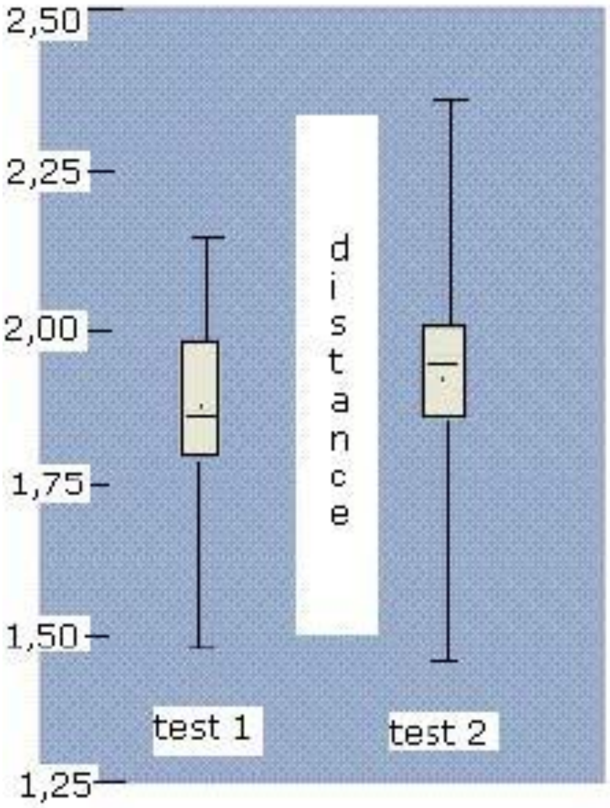


Fig 3 Stroke distance of Test 1 (left) and Test 2 (right)

DISCUSSION and CONCLUSION

Comparing the results of pre-and post-test it is obvious that the stroke distance increased at a similar speed. This can be also seen in the development of the stroke index, which comprises both speed and the stroke distance.

After six weeks training, including a SDA-M based intervention nearly the same average speed was reached by using less stroke cycles. The specific work on the identified stroking problems triggered most of the swimmers to modify their motion sequences. Longer stroke distance indicates an increased effect of the stroking action. In combination with a lower stroke rate a total increase of efficiency is obvious. Even though the change was not statistically significant the intervention made an impact: The participating swimmers increased their cognitive ability and thus enhanced their own power to improve their aquatic space activities.

Furthermore, many swimmers could not stabilize their motion sequence because of the relatively short time of practise after intervention. Even if the SDA-M based stroking instructions caused large-scale changes, the tested swimmers were not able to stabilize the new motion sequence in less than six weeks. Trying to swim at maximum speed, either they failed to produce an optimized constant motion sequence or they did not reach maximum speed because the test was done some days after main competition. This special group of swimmers would need more time to stabilize and automate their motion sequence at a slow speed (cf. Sweetenham/Atkinson 2003, Maglischo 2003).

The selected method stands the test, but in future it will be important to study this type of training in the domain of motion control and motion learning, for example with a longer time for practise after intervention. Using an individual SDA-M based instruction improves the teaching of swimming movements, not only because of the better structured communication. In conclusion, an effect of mental-representation-research based intervention on the stroking ability of age-group swimmers is possible and likely.

REFERENCES

Arellano R, Brown P, Cappaert J, Nelson RC (1994). Analysis of the 50-, 100-and 200-m freestyle swimmers at the 1992 Olympic Games. Journal of Applied Biomechanics 19. 189-1999.

Dekerle J, Nesi X, Lefevre T, Depretz S, Sidney M, Marchand FH, Pelayo P (2005). Stroking parameters in front crawl swimming and maximal lactate steady state speed. Int. J of Sports Med. 26, 53-58.

Engel F/ Schack T (2001). Das Coachingkonzept ProMent in der Praxis.

Maglischo E (2003). Swimming even fastest. Champaign: Human Kinetics.

Reischle K (1988). Biomechanik des Schwimmens. Bockenem: Fahnemann.

Rudolph K (2002). Zum Training der Kurzstrecken im Schwimmen. Leistungssport 1/2002, 46-53.

Sander RH (1999). Mid-Pool technique analysis: an alternative to the stroke length/stroke rate approach. In: Chien EP/ Chung PK (1999). The XIIIth FINA World Sports Medicine Congress. Aquatic Sports Medicine for the New Century, 83-95.

Schack T, Bar-Eli M (2007). Psychological Factors of Technical Preparation. In: Blumenstein B, Lidor R, Tenenbaum G (eds.): Psychology of Sport Training. Perspectives on Sport and Exercise Psychology, 62-103.

Schack T/ Mechsner F(2006). Representation of motor skills in human long-term

memory.
Neuroscience Letters, 391, 77-81.
Schack T (1999). Relation of cognitive representation and performance in extreme-surfing. In: Wachsmuth I, Jung, KogWis99 Proceedings der 4. Fachtagung für Kognitionswissenschaft. Vom 28. September -1. Oktober 1999 in Bielefeld, 207-212.
Sweetenham B, Atkinson J (2003): Championship Swim Training. Champaign: Human Kinetics.
Ungerechts BE, Schack T (2006). Mental representation of swimming strokes. In: Vilas-Boas JP, Alves, F, Marques A. (2006). Biomechanics and Medicine in Swimming. X. Portugese Journal of Sport Sciences. Vol. 6, Suppl. 2, 346-348.

Trajectory of crawl hand motion analyzed for elite age-group swimmers

Anna C Schmidt[1], Bodo E Ungerechts[2]

[1] University of Göttingen, Department of Society and Training, Germany

[2] University of Bielefeld, Department of Neurocognition and Action – Biomechanics, Germany

A judgment of arm motion below waterline based on observation from pool deck is not always sufficient to determine the effectivity of the action. For this purpose Reischle (1979) proposed to film the hand motion using fixed underwater cameras. Using one camera the 3-D-motion of the hand can be represented by a 2-D-trajectory in a plane; mostly the sagittal plane is represented and the components forwards / backwards and upwards / downwards can be investigated. Using a fixed camera instead of a panning one the hand motion resembles a cycloid shape (a curve generated by a curve rolling on another curve) with trocoid property, namely the exit point is in front of the entry point of the hand. This is the topographical basis of the interaction between hand and water, called water-view. A 2-D-trajectory can be analyzed quantitatively. The purpose of this paper is to compare the sagittal trajectory of age-group swimmers before and after an intervention and a 3rd time without intervention.

Key words: *crawl stroke, hand trajectory, age-group swimmers*

INTRODUCTION

Activities in aquatic space like crawl stroke swimming are traditionally viewed at from a body oriented position. The motion of limbs is considered to be more essential in comparison to the motion of surrounding water. Beside this aspect the details of the actions below waterline cannot be determined easily due to disturbed visibility and the fact that obviously everything is in motion. In water, in contrast to movements on land, swimmers do not find a firm and fixed counter bearings to apply force – except when pushing from the wall-. To propel the total body, swimmers have to change the motion of water-mass –producing momentum-. In reaction to this momentum the total body is moved. Hence, the interaction between limbs and aquatic space makes self-propulsion possible.

The motion of water-mass is invisible, unless some dye is added to the zone of activity.

Then the trajectory of the moving limb can be detected more easily. Counsilman (1971) presented already underwater pattern of elite swimmers' hands and established a concept of propulsion, called Bernoulli Principle. The approach "to observe hand with relation to still water" was essential for the concept. Since the hand is moving in a 3-D aquatic space at least two fixed cameras are necessary to make representation of spatial hand pattern possible. For some practical reasons quite often one fixed camera is used and a 2-D trajectory of a hand is presented. The 2-D trajectory is mostly restricted to the following directions: forward/backwards and upwards/downwards. The compontent inwards/outwards cannot be detected in this case.

Typical spatial patterns of crawl stroke were presented e.g. by Schleihauf (1983) and were used as a didactical tool to understand the complexity of spatial compontents of lift and drag and their contrubution to forces in and against swimming direction.

Fig. 1 Spatial patterns of crawl stroke (left: trajectory of hand action including a remarkable "shoulder" during upward orientation; right: in-/outwards-direction)

Hoecke et al (1975) used 2-D traces as a visual information in learning strategies and pointed out that traces "obtain a demonstration of motor process" and are "records of actual skill level" (although they distinguished sections of the curve into "phases" no time marks were represented). They paid attention if the entering phase was long/short or if the middle part was below the swimmers' belly and the length of the "horizontal working path". Reischle (1979) established some defined structural lines by which a 2-D trajectory can be described quantitatively. The structural lines were (Fig 2): (1) distance between point of entry and end of forward-downward-phase, (2) distance between end of forward-downward-phase and end of backward-upward-phase, (3) the deepest point and (4) the sum (1 – 2) which can be positive or negative (called "slippage").

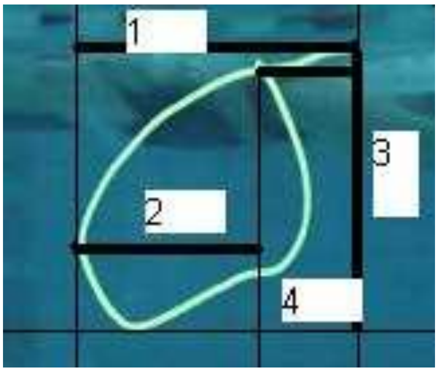


Fig. 2 The 2-trajectory of the fingertip of a crawl-stroke swimmer with structural lines to enable quantitative analysis; numbers are explained above (Arellano, 1991)

If (1) is comparatively longer there is "low acceleration of the hand at high total body speed" and if (2) is comparatively shorter the "efficiency of action" is higher. The purpose of this paper is the comparison of 2-D hand trajectorys of age-group crawl swimmers before and after an intervention in comparison to a control group of swimmers without intervention.

METHODS

In this study 22 junior swimmers were asked to swim crawl fast at 25 m – pushing from the wall. During that sprint the time over 10 m distance –between 10 to 20 m-was taken and the underwater action of the arm/hand was videotaped. The underwater videos were used to make the trajectory of the hand visible by using Dartfish-software. From the 2-D trajectory with the components: forwards/backwards and upwards/downwards four lines were determined as defined in Fig 2. There was a pre-and a post-test about 6 week apart. In the 6 weeks these swimmers received individual technical advice by the coach during the regular training. The swimmers were just preparing for their first participation for National Junior Championships.

RESULTS

The trajectory of the trace in most cases resembles a cycloid shape (a curve generated by a curve rolling on another curve) with trocoid property, namely the exit point is in front of the entry point of the hand. The junior swimmers' hand is moved actively downwards and during the upwards action seldom a "shoulder" in upward section can be seen in comparison to the trajectory in Fig 1.

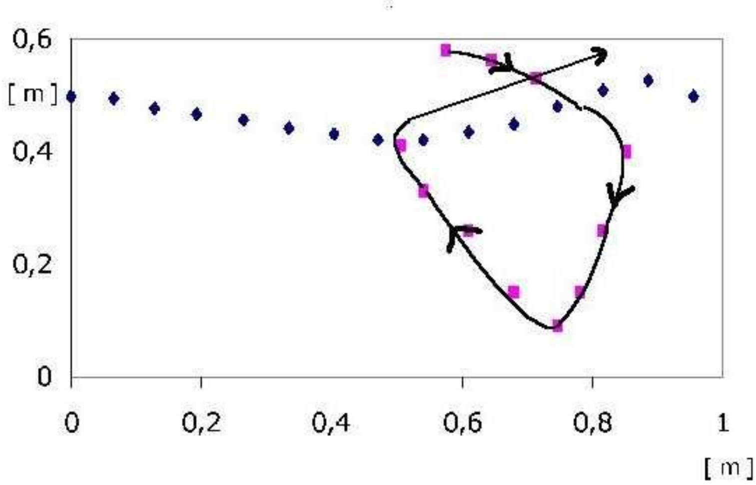


Fig. 3 An example of the dimensions of a) the cycloid shaped trajectory of the hand and b) the forward moved shoulder.

The diameter of the cycloid shaped trajectory is –in relation to the distance the shoulder moves per cycle-more or less small. In Fig. 3 the ratio is about 0,35 which means the largest distance the hand moves in horizontal direction, diameter of the cycloid shaped trajectory, is about 0,35 m whereas the shoulders moves about 1,00 m ahead.

Results for the structural lines were as follows

Structural line	Range [m]	Mean & SD [m]	Regression via speed	Coefficient
1	0.61 – 1.02	0.80 (±0.14)	y = 0.7301x -0.3077	r = 0.62
2	0.52 – 0.83	0.64 (±0.10)	y = -0.0239x + 0.6754	r = 0.03
3	0.54 – 1.07	0.69 (±0.15)	y = 0.754x -0.9832	r = 0.75
4	-0.15 – 0.30	0.16 (±0.12)	y = 0.6611x -0.3188	r = 0.55
5	0.50 – 0.84	0.66 (±0.11)	y = 0.168x + 0.4024	r = 0.18

At the first glance the correlation cofficient are take as guide lines: the order is (3), (1) and (4). The correlation cofficients of (2) and (5) indicates that the regression lines are more or less horizontal which means that the structural lines is not really changing due to speed changes. Structural line (1), the distance between point of entry and end of forward-downward-phase = |0,61 – 1,02| m and is sufficiently related to speed. Structural line (2), the distance between end of forward-downward-phase and end of backward-upward-phase = |0,52 – 0,83| m is not related to speed. Structural line (3), the deepest point = |0,54 – 1,07| m is well related to speed. Structural line (4), the sum (1 – 2) = |-0,15 – 0,30| m and is sufficiently related to speed. The width of the cycloid (5) = |0,50 – 0,84| is not well related to speed.

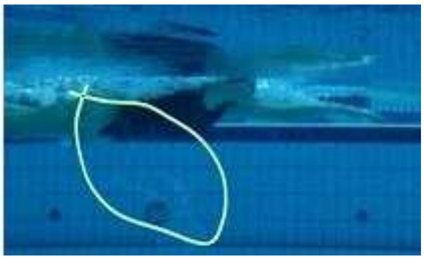


Fig. 4 The cycloid shaped trajectory of a female swimmer

The statistical means for females in three different tests

Parameter	**test 1** (mean)	test 1 std	**test 2** (mean)	test 2 std	**test 3** (mean)	test 3 std
u(25m) [m/s]	1.48	±0.08	1.44	±0.13	1.41	±0.12
s(exit-entry) [m]	0.09	±0.09	0.15	±0.12	0.14	±0.13
w(cycloid) [m]	0.56	±0.11	0.62	±0.09	0.61	±0.09

Fig. 5 The cycloid shaped trajectory of a male swimmer

The statistical means for males in three different tests

parameter	**test 1** (mean)	test 1 std	**test 2** (mean)	test 2 std	**test 3** (mean)	test 3 std
u(25m) [m/s]	1.57	±0.09	1.50	±0.13	1.50	±0.10
s(exit-entry) [m]	0.07	±0.09	0.15	±0.15	0.13	±0.22
w(cycloid) [m]	0.57	±0.08	0.65	±0.08	0.65	±0.07

It is obvious that the speed u(10m) was highest in test 1, however with complete different s(exit-entry) data. Quite surprising is the fact that the structural lines are very similar in both groups which belong the different speed clusters. The comparison of the 2-D trajectory of age-group swimmers before and after an intervention and a 3rd time without special intervention revealed that the width of the cycloid, w(cycloid) was remarkably increased in test 2. This outcome is supposed to be an indication that the action of the hand has become more effective because the component parallel to swimming direction –which includes the “hidden” inward/outward component-was increased.

DISCUSSION

The trajectory of the hand is traditionally of major interest. There is nearly no sport else for which the hand action is so detailed described like swimming strokes. The hand is moved simultaneously with the body and is the origin of thrust production. There is a conviction that the skillness to move the hand properly is strongly related to the distance a body is moved per cycle.

The discripancy between the wide-spread concept of moving the hand horozontally backwards in order to propel the body forward and occurance of a cycloid shape of the 2-D trajectory is still a challenge. In former times when no idea of vortex-induced propulsion exists the cycloid shape was fitted to the so called Bernoulli propulsion which require a path of the hand other than horizontally backwards. However, it was demonstrated that Bernoulli based lift approach will not explain the momentum needed to reach high swimming speed as shown by human swimmers. The cycloid shape of hand’s trajectory does not give a clue to what extend the hand moves inwards or outwards.

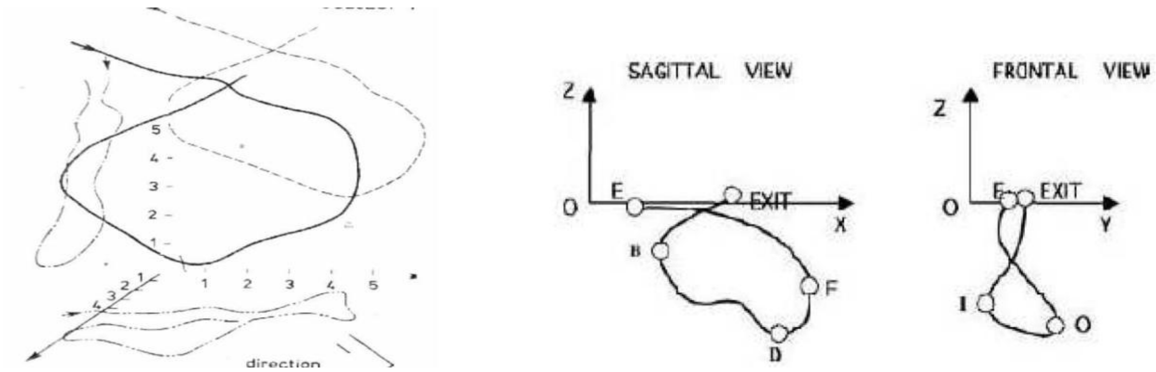


Fig. 6 Representations of 3 D – trajectories of the hand in crawl stroke swimming

The trajectory presently gives no hints if it is combined with jet-induced momentum or not because it is a kinematical treatment. It is assumed that a trajectory with an "indent" (in Fig. 1) represents the bending of the elbow when the shoulder is above the acting arm. Furthermore it is assumed that the diameter of the "cycloid" depends on the skill of a swimmer to produce momentum. This is likely provided the hand exits water in front of its entry.

Arellano (1991) also studied age-group swimmers. They summarized that kinematical data were not susceptible to change in three month time. The following table is presenting the data ranges of both studies:

Structural line	Schmidt/Ungerechts	Arellano et al (1991)
(1) entry – (end of forward-downward)	|0.61 – 1.02| m	|0.43 – 0.54| m
(2) (end forward-downward) – (end backward upward)	|0.52 – 0.83| m	|0.56 – 0.59| m
(3) deepest point	|0.54 – 1.07| m	|0.58 – 0.61| m
(4) (1) – (2)	| -0.15 – 0.30| m	|-0.06 – 0.17| m

Due to the fact that body size may differ remarkably which will influence the possibility to reach greater depth, the figures are in the same ranges.

Larger s(exit-entry) data are considered as indication of effective hand action. Based on the regression coefficent this study supports this approach since larger s(exit-entry)-lines are connected to faster swimming speeds. Comparison of the data of the slower group (females) and faster group (males) may support the opinion that the relevant structural lines are mainly determined by degree of skills to manipulate water mass instead of anthropometric data or strength.

REFERENCES

Arellano R., Pardillo S. (1991). An evaluation of changes in the crwal-stroke techniques during training periods in a swimming season. In: D.MacLaren, T Reilly, A.Lees (eds.) Swimming Science VI. E & F FN Spon, London:143-149.

Hoecke G., Gruendler G. (1975) . Use of light trace photography in teaching swimming. In: L. Lewillie, J.P. Clarys (eds.) Swimming II. University Park Press, Baltimore: 194-206.

Reischle K. (1979). A kinematic investigation of meovement patterns in swimming with photo optical methods. In: J Terrauds, E. W. Bedingfield (eds.) Swimming III, Unversity Park Press, Baltimore: 127-136.

Schleihauf R., Gray L., DeRose, J. (1983). Three-diemensional analysis of hand porpulsion in the sprint front crawl stroke. In: A.P.Hollander, P.A. Huiing, G. de Groot (eds.) Biomechanics and Medicine in Swimming. Human Kinetics Publishers, Champaign, IL.: 173-183.

Poster presentation

Day 3 – 27th March

Hydrotherapy for the children with autism spectrum disorders

Sho Onodera, Kazuki Nishimura, Kumiko Ono, Tomoko Fujisawa, Kazutoshi Seki, Akira Yoshioka, Terumasa Takahara, Yasuo Ishida, Mayo Komiyama, Moe Kitamura, Masayoshi Hirao and Baik Wooram

Department of Health and Sports Sciences, Kawasaki University of Medical Welfare,

Abstract: The purpose of this study was to investigate the relationship between the activity of individual support and the order of achievement of the tasks during hydrotherapy. Subjects were thirteen children with autism spectrum disorders (ASD). We obtained informed consent from participating members. We examined a five-point estimation during one year. Grade evaluation was in two stages; can do and cannot do, using a video analysis. The order of achivement of the tasks was Beginner's class: ①touching up the goals, ②starting with signs, ③flutter kicks, ④face immersion, ⑤back floating and Middle class: ① back floating, ②flutter kicks, ③crawl arm strokes, ④back floating and kicks, ⑤breath at the forward. The order of achievement of children with ASD was consistent with the order of a healthy parson both in the beginner's class and a middle class. These results suggest that the activity of individual support and the establishment of the order of the tasks are a practical method for hydrotherapy.

Key word: *hydrotherapy, autism spectrum disorders (ASD), individual support, and the order of achievement of the tasks.*

Introduction: We have been promoting hydrotherapy for children with autism spectrum disorders (ASD) since 2001. Autism Spectrum Disorder is considered to possess the continuous situational image (spectrum) that would make the combination of the three spectrums 'the main spectrum'. The three spectrums are as follows: 1. Impairments in the social-mutual intercourse that make it difficult to maintain and form the relationships with other people. 2. Impairments in the communication that make it hard to comprehend and utter words. 3. Imaginary disorders (extreme interests and particular behaviors). Moreover, those children with ASD are likely to develop, not equally, in the field of exercise, such as awkward physical activities. Hydrotherapy based upon the assumption (movement) that hydrotherapy is based upon the assumption that the promotion of physical activities of children will promote development in all functions, such as exercise activities, and besides, will also aid to promote the almighty developments. Purpose: The purpose of this study was to investigate the relationship between the activity of individual support and the order of achievement of the tasks during the individual support program.

Methods: Subjects were thirteen children (age: 10.1±3.3 yrs, body height: 131.0±10.0cm, body weight: 31.6±9.7kg) with ASD. The same number of children's parents also took part in the program in the swimming pool. Beginner's class was the member of eight children. Middle class was the member of five children. We obtained informed consent from participating members. We explained thoroughly to the parents, according to the summaries made at the Helsinki Proclaims, about the purpose, method, results in the future, demerits, and environments without risks of our research, emergencies as well, and get approved by the participants. We carried out a two-hour hydrotherapy program including preparatory exercise, free play, circuit, individual support program, and dance in the swimming pool. An individual support program of twenty minutes was consistent of start with signs, touching up the goals, face immersion, flutter kicks, back floating (Beginner's class) and crawl arm strokes, flutter kicks, breath at the forward, back floating, back floating and kicks (Middle class). The average water temperature was at 30.1 degrees Celsius, while the room temperature was 33.5. We examined a five-point estimation during one year. Grade evaluation was in two stages; can do and cannot do, using a video analysis.

Results and Discussion: Table 1 shows the changes of number of persons achieved the tasks in a Beginners' class. Table 2 shows the changes of children individual evaluation in a Beginners' class. The order of achivement of the tasks of Beginner’s class was ① touching up the goals, ②starting with signs, ③flutter kicks, ④face immersion, ⑤ back floating. Table 3 shows the changes of number of persons achieved the tasks in a Middle class. Table 4 shows the changes of children individual evaluation in a middle class. The order of achivement of the tasks Middle class was ①back floating, ②flutter kicks, ③crawl arm strokes, ④back floating and kicks, ⑤breath at the forward. Those tendencies suggest that the order of achievement of children with ASD is consistent with the order of a healthy parson not only in a middle class but also beginners’ class. Those results agreed with the order of teaching of a healthy parson in the textbook of Japan Swimming Federation and Swimming Club Association 2006. The difference between children with ASD and a healthy parson was a period of time. A period of an achievement of children with ASD was extremely longer rather than a healthy parson. Those results suggest that the activity of individual support and the establishment of the order of the tasks are a practical method for hydrotherapy.

In conclusion: the order of achievement of children with ASD is consistent with the order of a healthy parson.

Table 1　Changes of number of persons achieved the tasks in a Beginners' class.

Date＼Items	Starting with sign	Touching up the goal	Face immersion	Board kick	Back float
16 Apr	4	5	1	4	1
7 May	3	4	1	4	1
6 Aug	3	3	2	3	0
27 Aug	4	5	2	5	1
8 Oct	5	5	3	5	1
29 Oct	3	3	2	3	1
14 Jan	2	2	0	1	0
18 Feb	3	3	2	3	0
4 Mar	3	3	1	2	0

Table 2　Changes of children individual evaluation in a beginners' class.

(◎:can do first, ○:can do, ×:cannot do)

Subject A

Date＼Items	Starting with sign	Touching up the goal	Face immersion	Board kick	Back float
16 Apr	○	○	×	×	×
7 May	○	○	×	◎	×
6 Aug					
27 Aug					
8 Oct					
29 Oct					
14 Jan					
18 Feb					
4 Mar					

Subject B

Date＼Items	Starting with sign	Touching up the goal	Face immersion	Board kick	Back float
16 Apr					
7 May					
6 Aug	○	○	×	○	×
27 Aug	○	○	×	○	×
8 Oct	○	○	×	○	×
29 Oct	○	○	×	○	×
14 Jan	○	○	×	○	×
18 Feb	○	○	×	○	×
4 Mar	○	○	×	○	×

Subject C

Date＼Items	Starting with sign	Touching up the goal	Face immersion	Board kick	Back float
16 Apr	○	○	×	○	×
7 May	○	○	×	○	×
6 Aug	○	○	◎	○	×
27 Aug	○	○	○	○	×
8 Oct	○	○	○	○	×
29 Oct	○	○	○	○	×
14 Jan					
18 Feb	○	○	○	○	×
4 Mar	○	○	○	○	×

Subject D

Date＼Items	Starting with sign	Touching up the goal	Face immersion	Board kick	Back float
16 Apr	○	○	×	○	×
7 May					
6 Aug	○	○	◎	○	×
27 Aug					
8 Oct					
29 Oct					
14 Jan					
18 Feb					
4 Mar					

Subject E

Date＼Items	Starting with sign	Touching up the goal	Face immersion	Board kick	Back float
16 Apr	×	○	×	○	×
7 May	×	○	×	○	×
6 Aug					
27 Aug	×	○	×	○	×
8 Oct	◎	○	◎	○	×
29 Oct					
14 Jan					
18 Feb	○	○	○	○	×
4 Mar					

Subject F

Date＼Items	Starting with sign	Touching up the goal	Face immersion	Board kick	Back float
16 Apr					
7 May					
6 Aug					
27 Aug	○	○	×	○	×
8 Oct	○	○	×	○	×
29 Oct					
14 Jan					
18 Feb					
4 Mar					

Subject G

Date＼Items	Starting with sign	Touching up the goal	Face immersion	Board kick	Back float
16 Apr					
7 May					
6 Aug					
27 Aug					
8 Oct					
29 Oct					
14 Jan	○	○	×	×	×
18 Feb					
4 Mar	○	○	×	×	×

Subject H

Date＼Items	Starting with sign	Touching up the goal	Face immersion	Board kick	Back float
16 Apr	○	○	○	○	○
7 May	○	○	○	○	○
6 Aug					
27 Aug	○	○	○	○	○
8 Oct	○	○	○	○	○
29 Oct	○	○	○	○	○
14 Jan					
18 Feb					
4 Mar					

Table 3　Changes of number of persons achieved the tasks in a Middle class.

Date＼Items	Crawl arm stroke	Flutter kick	Breath at the forward	Back float	Back float and kick
16 Apr	2	1	0	4	0
7 May	2	3	0	3	0
6 Aug	4	4	0	4	1
27 Aug	3	3	1	3	1
8 Oct	2	2	0	2	2
29 Oct	2	2	1	2	1
14 Jan	3	3	2	2	1
18 Feb	3	3	1	2	2
4 Mar	3	3	2	3	2

Table 4　Changes of children individual evaluation in a middle class.
(◎:can do first, ○:can do, ×:cannot do)

Subject I

Date＼Items	Crawl arm stroke	Flutter kick	Breath at the forward	Back float	Back float and kick
16 Apr	×	×	×	○	×
7 May	×	◎	×	○	×
6 Aug	◎	○	×	○	×
27 Aug					
8 Oct					
29 Oct	○	○	×	○	◎
14 Jan	○	○	×	○	○
18 Feb	○	○	×	○	○
4 Mar	○	○	×	○	○

Subject L

Date＼Items	Crawl arm stroke	Flutter kick	Breath at the forward	Back float	Back float and kick
16 Apr	○	×	×	○	×
7 May	○	◎	×	○	×
6 Aug	○	○	×	○	×
27 Aug	○	○	×	○	×
8 Oct	○	○	×	○	◎
29 Oct					
14 Jan					
18 Feb	○	○	×	○	○
4 Mar					

Subject J

Date＼Items	Crawl arm stroke	Flutter kick	Breath at the forward	Back float	Back float and kick
16 Apr	×	×	×	○	×
7 May					
6 Aug	◎	◎	×	○	×
27 Aug	○	○	◎	○	×
8 Oct					
29 Oct	○	○	○	○	×
14 Jan	○	○	○	○	×
18 Feb					
4 Mar					

Subject M

Date＼Items	Crawl arm stroke	Flutter kick	Breath at the forward	Back float	Back float and kick
16 Apr					
7 May					
6 Aug					
27 Aug					
8 Oct					
29 Oct					
14 Jan	○	○	○	×	×
18 Feb	○	○	○	×	×
4 Mar	○	○	○	◎	×

Subject K

Date＼Items	Crawl arm stroke	Flutter kick	Breath at the forward	Back float	Back float and kick
16 Apr	○	○	×	○	×
7 May	○	○	×	○	×
6 Aug	○	○	×	○	◎
27 Aug	○	○	×	○	○
8 Oct	○	○	×	○	○
29 Oct					
14 Jan					
18 Feb					
4 Mar	○	○	◎	○	○

Reference

1 Cratty, B. J. (1969) Motor activity and the education of retardates. Philadelphia: Lea & Febiger.

2 Gesell, A. et al. (1950) The first five years of life. Methuen & Co. Ltd: London.

3 Gillberg, C. (1991) Clinical and neurological aspects of Asperger syndrome in six family studies. In U. Firth (Ed.). Autism and Asperger syndrome. Cambridge University Press: Cambridge, UK. 122-146.

4 Japan Swimming Federation and Swimming Club Association (2006) The textbook of Japan Swimming Federation and Swimming Club Association 2006. TAISHUKAN Publishing Co., Ltd. Tokyo

5 Kadesjö, B. Gillberg, C., Hagberg, B. (1999) Autism and Asperger syndrome in seven-year-old children : a total population study. J Autism Dev Disord 29: 327-331.

6 Keogh, J. F. (1968) Analysis of individual tasks in the Stott Test of motor impairment. department of Physical Education: University of California at Los Angeles, Technical Report . 2-68.

7 Onodera S. (2005) The study of hydrotherapy for autism and asperger syndrome. Report of Science and Technology Policies of the Ministry: 22−37

8 Wing, L. & Attwood, A. (1987) Syndromes of autism and atypical development. In Cohen, D. & Donnellan, A. (Eds.). Handbook of autism and pervasive developmental disorders: New York. 3-19.

A study about the variable of WAVING in Japanese finswimmers in the 50-m Surface and Apnea.

Kazushige Oshita[1, 3], Misaki Ross[2, 3], Kazushi Koizumi[4], Syunpei Kashimoto[5], Kouki Takahashi[1] and Masayuki Kawakami[1]

[1] Kurashiki University of Science and the Arts, Japan.

[2] TORAY Industries, Inc., Japan.

[3] Kansaikieikai, Japan.

[4] Nippon Sports Science University, Japan.

[5] UMINOHOSHI Co. Ltd., Japan.

We investigated about the variables of WAVING, such as the swimming velocity (SV), the WAVING rate (WR; WAVING per second), the WAVING length (WL; distance per WAVING) in the 50-m Surface (SF) and Apnea (AP). The subjects were five expert (EX) and four non-expert males (NE). The SV of EX was faster than that of NE in the SF (2.7 vs. 2.3 m/ sec) and the AP (3.1 vs. 2.6 m/ sec). The WL of EX was longer than that of NE in the SF (1.0 vs. 0.9 meter) and the AP (1.1 vs. 1.0 meter). The WR in the SF and the AP were not significant difference between EX (2.8 and 2.7 Hz) and NE (2.7 and 2.6 Hz). Moreover, there was a significant positive relationship between SV and WL in the SF or the AP. However, there was no significant relationship between SV and WR in the SF or the AP. These results suggest that WL is concluded to be an important factor that influences the SV in the 50-m SF and AP.

Key words: *Fin swimming, Surface, Apnea, WAVING rate, WAVING lenght, Swimming velocity*

INTRODUCTION

Finswimming is a speed competition sport practiced on the surface of water or underwater with monofins or two fins. The Surface event (SF) is a finswimming event, and it refers to progression with monofins or with two fins on the surface of water. In swimming pools, distances of 50-m, 100-m, 200-m, 400-m, 800-m, and 1500-m are recognized officially by the World Underwater Federation (12). The male world record in the 50-m SF on 1st January, 2006 is 15.20-sec. Similar to the motion of dolphins, propulsion bears on the vertical displacement of the whole body (11). The vertical displacement of the body during the stroke cycle has been described as wave-like (10). This form of swimming is defined as “WAVING” in finswimming.

In the swimming event, the mean swimming velocity (SV) during stroking is the product of the mean stroke length (equivalent to the distance the body is displaced during one complete stroke cycle; SL) and the mean stroke rate (number of stroke cycles per second or minute; SR) (1-3). This relationship can be expressed as SV = SR * SL. If this concept is applied to SF, the SV of SF may be used to product of the WAVING length (WL; equivalent to the distance the body is displaced during one complete WAVING cycle) and mean WAVING rate (WR; number of WAVING cycles per second or minute). A previous study on the kinematics of a 100-m SF showed that novices were slower than elite finswimmers, although their WR was higher (4). However, the influence of WL is unknown. Further, the 100-m swimming was affected by the turn technique in both long- and short-course swimming pools. Therefore, the WAVING technique is not represented by the variables alone. Based on our knowledge, we concluded that elites take a shorter turn time than novices. However, the variables of WAVING in the 50-m SF were not taken into consideration. Their analysis may provide useful information to coaches and technicians for the enhancement of the SF performance.

In the present study, we aim to quantify the variables of WAVING, such as SV, WR, WL, and practice level in Japanese finswimmers in the 50-m SF.

METHODS

The subjects chosen were five expert males (EX; 22 +/- 3 years), who were finalists in the Japanese Championship in 2005 in the 50-m SF or members of the Japanese National Team and four non-expert males (NE; 23 +/- 2 years), who were non-finalists in the Japanese Championship in 2005 in the 50-m SF.

The experiment was carried out in an indoor long-course pool (water temperature was 27.2 +/- 0.8 degrees Celsius). After a standardized warm up, the subjects were instructed to perform the 50-m SF with their standard monofins and snorkel. These experiments followed the rules with a prescribed by the World Underwater Federation (12).

A video image was recorded with a digital video camera (Handy Cam Vision, Sony, Japan) in order to record the sagittal views. The camera was placed on a balcony in the pool, with the optical axis parallel to the swimming lane. The width of the covered field was 10 m between the 20th and the 30th meter of the 50-m swim.

The collected video image was downloaded on to a PC and analyzed by a kinematic analysis software (Physicalsoft-Motion Viewer, ver 1.0.0.2,). The downloaded video image made a frame (30 fps) and input an analysis point into the tiptoe part (boots part of the monofin) by manual operation in each field. From these data, it defined one WAVING as follows, and analyzed the variables of WAVING. The onset of WAVING define as the situation that an analysis point rose most perpendicularly, and the end of WAVING define as the situation that an analysis point rose most again (Figure 1). The software analyzed five WAVING and defined WR and WL as the WAVING frequency per second, and traveled distance (meter) per WAVING, respectively.

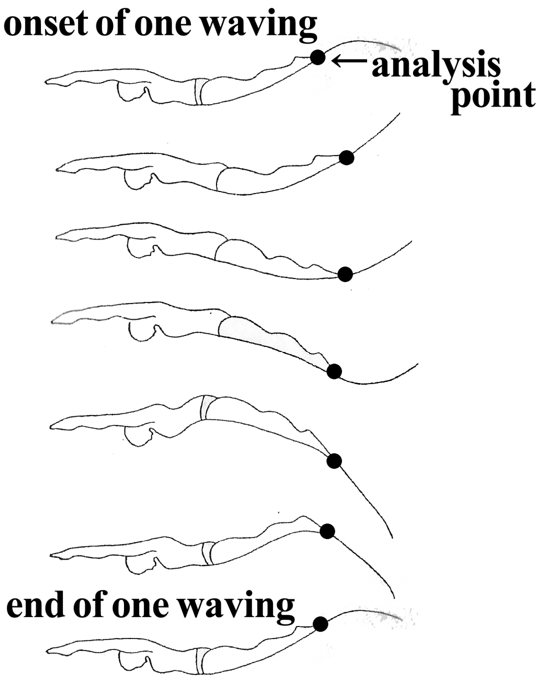


Figure 1. Definition of one WAVING.

The observed values were expressed as the mean and standard deviations. All analyses were performed with the JSTAT (version 11.1 for Windows) software. The differences between EX and NE in each mean value were tested using Student's t test. Pearson's correlation coefficient was used to examine the interrelationship between SV and WR and that between SV and WL. In these statistical analyses, the significance level was chosen to be 0.05.

RESULT AND DISCUSSION

Table 1. The variables of WAVING in the subjects.

Variables	Events	Expert MEAN ± S. D.	Non-expert MEAN ± S. D.
Swimming Velocity (m/ sec)	**Surface**	**2.73 ± 0.05**	**2.26 ± 0.12** *
	Apnea	**3.05 ± 0.09** †	**2.60 ± 0.08** *,†
WAVING Rate (Hz)	**Surface**	**2.80 ± 0.12**	**2.66 ± 0.11**
	Apnea	**2.72 ± 0.08**	**2.60 ± 0.16**
WAVING Length (m)	**Surface**	**0.97 ± 0.03**	**0.85 ± 0.06** *
	Apnea	**1.12 ± 0.04** †	**1.00 ± 0.06*** *,†

*; $P < 0.05$ vs. "Expert". †; $P < 0.05$ vs. "Surface".

The SV of EX was faster than that of NE, and the WL of EX was longer than that of NE (Table 1). Moreover, there was a significant positive relationship between SV and WR (Fig. 2). These results are suggested that that WL influences the SV in the 50-m SF and AP. Increasing the driving force and/or reducing the drag are important factors to lengthen WL. A previous study on the kinematics of SF suggested that elite finswimmers achieve such a feat due to a weaker knee bending and low upper limb pitching, thereby concomitantly reducing their frontal area and drag (4, 7). Moreover, they optimally transform potential energy into kinetic energy during the WAVING cycles, and transfer it caudally, tantamount contributing to a propulsive whip-like action (9, 13). These reports support our findings; therefore, WL is concluded to be an important factor that influences the SV of SF and AP.

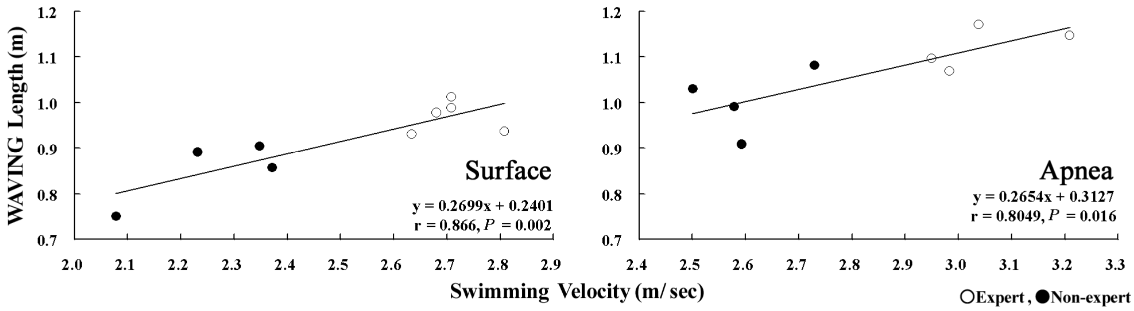


Figure 2. The relationships between WAVING length and swimming velocity in the 50-m Surface and Apnea

However, there was no significant difference between EX and NE with regard to WR (Table 1). Moreover, there was no significant relationship between SV and WR (Fig. 3). These results suggest that WR does not influence the SV in the 50-m SF and AP. Gautier et al. (4) suggested that novices were slower than elite finswimmers, although their WR was higher in the 100-m SF. This report indicates that WR is probably an important factor in SV, and its values are different from those obtained in our experiment. However, in this study, the WR was 2.80 and 2.66, whereas the WR in their report was 1.88 and 1.54. Furthermore, our SV was faster than that in their report. Moreover, WR in this study resemble that of the world's top athlete (6). In other words, the WR may be limited in humans sporting monofins. Therefore, it is thought that it is necessary to lengthen the WL for SV improvement in this case.

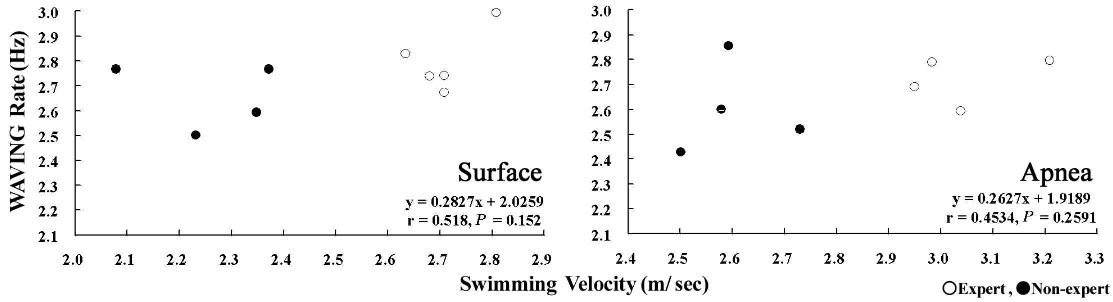


Figure 3. The relationships between WAVING rate and swimming velocity in the 50-m Surface and Apnea

This study investigates the simple variables of WAVING, and some problems are considered and analyzed. Initially, we intended to investigate of the variables of WAVING only during the midpoint of the 50-m distance. Therefore, it may be different from the case where the entire race was examined. Furthermore, the length of the limbs may also influence WR. A larger muscle-shortening velocity is required with a longer moment arm in order to achieve a certain joint angular velocity, and this resulted in a smaller muscle force development because of the force–velocity relation of the muscle (5). The longer moment arm results in smaller joint moment development, power, and work outputs in fast motions. These are being the problems that will be investigated in the future.

CONCLUSION

We investigated the variables of WAVING in the 50-m SF and AP. The SV of EX was faster than that of NE, and the WL of EX was longer than that of NE. There was no significant difference between EX and NE with regard to WR. Moreover, there was a significant positive relationship between SV and WL. However, there was no significant relationship between SV and WR. These results suggest that WL is concluded to be an important factor that influences the SV in the 50-m SF and AP.

REFERENCES

1. Aujouannet YA, Bonifazi M, Hintzy F, Vuillerme N and Rouard AH (2006). Effects of a high-intensity swim test on kinematic parameters in high-level athletes. Appl Physiol Nutr Metab, 31: 150-158.
2. Craig AB Jr and Pendergast DR (1979). Relationships of stroke rate, distance per stroke, and velocity in competitive swimming. Med Sci Sports Exerc, 11: 278-283.
3. Craig AB Jr, Skehan PL, Pawelczyk JA and Boomer WL (1985). Velocity, stroke rate, and distance per stroke during elite swimming competition. Med Sci Sports

Exerc, 17: 625-634.
4. Gautier J, Baly L, Zanone PG. and Watier B (2004). A kinematic study of finswimming at surface. J Sports Sci Med, 3: 91 – 95.
5. Nagano A and Komura T (2003). Longer moment arm results in smaller joint moment development, power and work outputs in fast motions. J Biomech, 36: 1675-1681.
6. Oshita, K, Ross M, Koizumi K, Kashimoto S, Takahashi K and Kawakami M (2007). A record characteristic of the finswimming, compared with a swimming (free-style and butterfly). The proceedings of the annual meetings of Japanese society of sciences in swimming and water exercise 45-48 (in Japanese).
7. Nicolas G., Bideau B, Colobert B and Berton E (2007). How are Strouhal number, drag, and efficiency adjusted in high level underwater monofin-swimming? Hum Mov Sci, 26: 426-442.
8. Pendergast DR, Mollendorf J, Logue C and Samimy S (2003). Evaluation of fins used in underwater swimming. Undersea Hyperb Med, 30: 57-73.
9. Rejman M and Ochmann B (2007). Functional Model of monofin swimming technique based on the construction of neural networks. J Sports Sci Med, 6: 193-203.
10. Ungerechts BE (1982). A comparison of the movements of the rear parts of dolphins and butterfly swimmers. In: Hollander AP (Ed). Biomechanics and Medicine in Swimming. Champaign: Human Kinetics, 215-221.
11. Videler J and Kamermans P (1985). Differences between upstroke and downstroke in swimming dolphins. J Exp Biol, 119: 265-274.
12. World Underwater Federation (2006). Finswimming international rules. World Underwater Federation: 2006.
13. Zamparo P, Pendergast DR, Termin B and Minetti AE (2002). How fins affect the economy and efficiency of human swimming. J Exp Biol, 205: 2665-2676.

Effect of non-uniform skin temperature distribution on thermoregulatory responses during immersion

Hitoshi Wakabayashi[1], Koichi Kaneda[2], Daisuke Sato[2], Yutaka Tochihara[1], Takeo Nomura[2]

[1] Faculty of Design, Kyushu University, Japan

[2] Doctoral Program in Comprehensive Human Science, University of Tsukuba, Japan

The present study investigated the effect of non-uniform skin temperature distribution on thermoregulatory responses and subjective thermal sensation during immersion. Ten healthy male subjects carried out 60 min water immersion twice, once with uniform (UST) and once with non-uniform (NUST) skin temperature conditions. In UST condition, subjects immersed at 29°C in the naked condition, while in NUST condition, subjects immersed at 26°C with a partial coverage wetsuit (PCWS). The PCWS covers trunks, upper arms, and thighs. The non-uniform skin temperature distribution, higher at trunk and lower at distal extremities, was observed in NUST condition. Shivering thermogenesis was not influenced by the skin temperature distribution. On the other hand, the tissue insulation (I_{tissue}) was significantly higher in NUST condition compared to UST condition. The increase of I_{tissue} might have been caused by the peripheral vasoconstriction induced by the cold input from the distal extremities. The higher I_{tissue} in NUST condition might lead to the significantly higher esophageal temperature compared to UST condition. No difference was observed in thermal sensation between two conditions. Subjects felt slightly more comfortable in NUST condition than in UST condition.

Key words: *skin temperature distribution, partial coverage wetsuit, water immersion, tissue insulation, thermal sensation*

INTRODUCTION

The thermal conductance of water is approximately 25 times greater than that of air. Consequently, body heat is rapidly conducted away from human skin to the water. Wearing an additional layer of insulation on the skin surface is a convenient means to reduce convective heat loss. Many investigators have studied the effects of wetsuits, which reduced the decrease of core temperature (Kang et al., 1983). In our previous studies, the effect of a partial coverage wetsuit (PCWS) during cool water immersion were examined (Wakabayashi et al., 2005; 2006; 2007), and their specific characteristic differing from wetsuits was observed. The tissue insulation (I_{tissue}) with a PCWS was similar to the naked condition, while previous study reported that wearing wetsuits decreased I_{tissue} (Kang et al., 1983). PCWS directly exposed distal extremities to water more than wetsuits, which might be sufficient sensory input to induce vasoconstriction similar to the naked condition. Choi et al. (2003) studied the effect of uniform and non-uniform skin temperature on thermal exchanges in water using specially designed water-perfused garment and thermo-circulation system which controlled five skin temperature regions individually. They described that higher skin temperature of the trunk attenuates shivering in cold water compared to the uniform condition on the same mean skin temperature.

The present study investigated the effect of non-uniform skin temperature distribution wearing a PCWS on thermoregulatory response during water immersion.

METHODS

Ten healthy male subjects volunteered for this study. Each subject carried out the protocol twice, once with uniform (UST) and once with non-uniform (NUST) skin temperature conditions. In UST condition, subjects with ordinary swim trunks were immersed up to their neck level for 60 min at 29°C water. In NUST condition, subjects wore a PCWS at 26°C water. In both conditions, their mean skin temperatures were similar. The PCWS used in this study was made of nylon-faced neoprene (2 mm thick), covered trunks, upper arms, thighs, and neck.

During the experiment, esophageal temperature (T_{es}) and 8 skin temperature regions were measured using thermistor sensors. The mean skin temperature ($\overline{T}_{sk}$), the skin temperature of the trunk and proximal extremities ($\overline{T}_{trunk}$) and the distal extremities ($\overline{T}_{limb}$) were calculated. The mean body temperature ($\overline{T}_{b}$) were calculated from T_{es} and $\overline{T}_{sk}$. Expired gases were continuously assessed using an automatic respiromonitor. Values of the oxygen uptake ($\dot{V}_{O_2}$), carbon dioxide elimination ($\dot{V}_{CO_2}$), and respiratory exchange ratio (RER) were averaged every 1 min. Total metabolic heat production (M) was calculated from $\dot{V}_{O_2}$ and RER. Metabolic heat production from the unit skin surface (M_s) was calculated using the formula: $M_s = 0.92 \cdot M / SA$. Body heat storage (S_s) was calculated from $\Delta\overline{T}_{b}$, body weight (BW) and the human body specific heat capacity (C_b) using the following formula: $S_s = C_b \cdot \Delta\overline{T}_{b} \cdot BW / SA$. Heat loss from the skin to the water (H_s) was calculated as $H_s = M_s - S_s$. Tissue insulation (I_{tissue}) was calculated as $I_{tissue} = (T_{es} - \overline{T}_{sk}) / H_s$. Subject's thermal sensation and thermal comfort were assessed every 5 minutes.

RESULTS and DISCUSSION

Changes in T_{es} and skin temperatures are shown in Fig. 1. In NUST condition, $\overline{T}_{trunk}$ was 30.1 ± 0.3°C, and $\overline{T}_{limb}$ was 26.5 ± 0.1°C at 60 min. The larger difference between $\overline{T}_{trunk}$ and $\overline{T}_{limb}$ was observed in NUST condition (3.6°C) compared to the smaller difference in UST condition (0.4°C) at 60 min. $\overline{T}_{sk}$ was significantly higher in UST condition than in NUST condition from 15 min to 60 min (p<0.05). T_{es} was significantly higher in NUST condition than in UST condition from 35 min to 60 min (p<0.05).

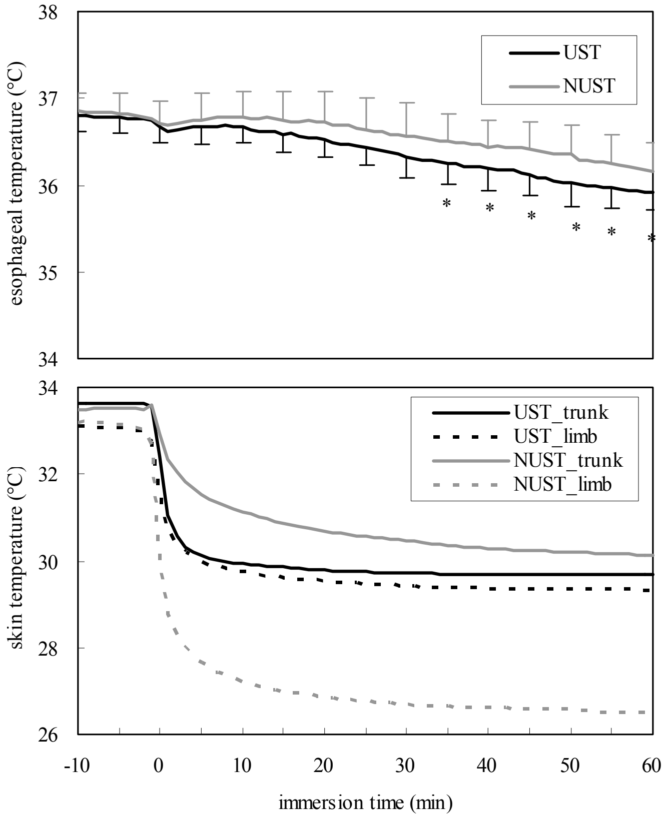


Fig. 1 Esophageal and skin temperature changes during immersion

The M_s, S_s and H_s showed no differences between the two conditions (Table 1). The I_{tissue} was significantly higher in NUST condition than in UST condition (p<0.05, Table 1).

Table 1 M_s, S_s, H_s and I_{tissue} during water immersion

		M_s ($W \cdot m^{-2}$)	S_s ($W \cdot m^{-2}$)	H_s ($W \cdot m^{-2}$)	I_{tissue} ($°C \cdot m^2 \cdot W^{-1}$)
NUST	mean	54.7	69.2	123.9	0.059
	(SD)	(9.0)	(6.7)	(8.0)	(0.006)
UST	mean	55.1	67.7	122.8	0.052 *
	(SD)	(11.2)	(6.8)	(7.9)	(0.005)

Choi et al. (2003) reported the significantly higher shivering thermo-genesis in UST condition compared to NUST condition at 28.4°C water. However, in this study no significant difference was observed in M_s between the two conditions. The difference between the previous report and our study might have been caused by the skin temperature of distal extremities. In this study the $\overline{T}_{limb}$ was around 26.5°C in NUST condition, which was higher than the previous report's skin temperature of hand and foot (24.7°C). The higher skin temperature of distal extremities in this study compared to the previous report might have led to the similar M_s results in both conditions. On the other hand, I_{tissue} in NUST condition was significantly higher than in UST condition (p<0.05), which corresponded with the previous report (Choi et al., 2003). The increment of I_{tissue} might have been caused by the vasoconstriction induced by the cold input from the distal extremities in NUST condition. The increment of I_{tissue} might have led to the slightly higher T_{es} in NUST condition.

Figure 2 shows the changes in thermal comfort during immersion. It was slightly uncomfortable in UST condition compared to NUST condition, and significant differences were observed at 40 and 60 min (p<0.05). On the other hand, no differences were observed in the thermal sensation between both conditions (Fig. 3).

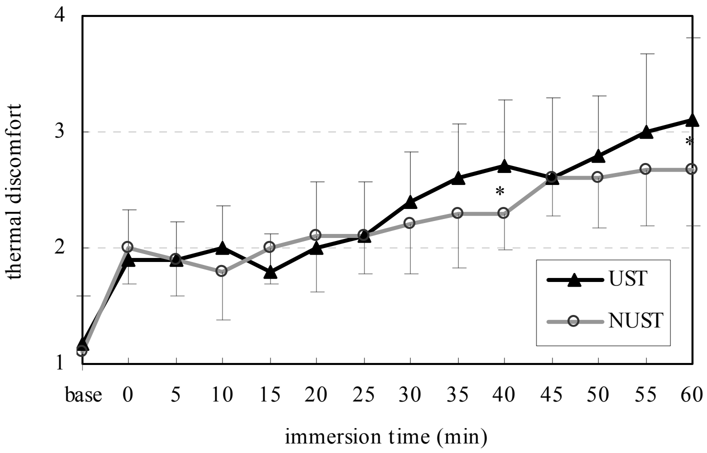


Fig. 2 Changes in thermal discomfort during immersion

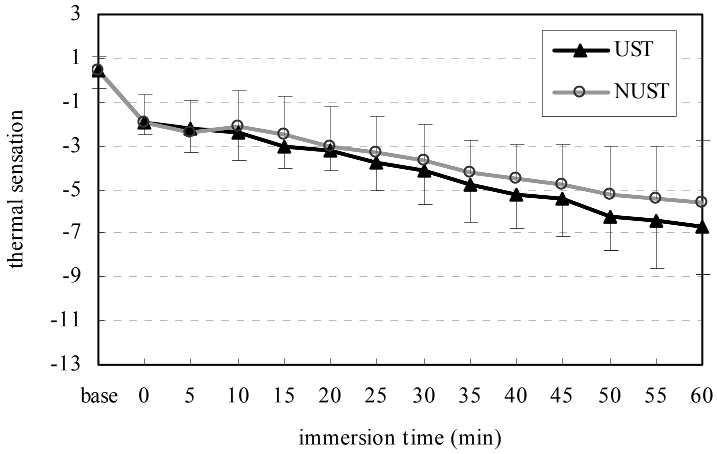


Fig. 3 Changes in thermal sensation during immersion

REFERENCE

1) Choi JK, Lee HS, Park YS, Shiraki K (2003) Effect of uniform and non-uniform skin temperature on thermal exchanges in water in humans. Int J Biometeorol 47(2): 80-86.

2) Kang DH, Park YS, Park YD, Lee IS, Yeon DS, Lee SH, Hong SY, Rennie DW, Hong SK (1983) Energetics of wet-suit diving in Korean women breath-hold divers. J Appl Physiol 54(6): 1702-1707.

3) Wakabayashi H, Kaneda K, Okura M, Nomura T (2007) Insulation and body temperature of prepubescent children wearing a thermal swimsuit during moderate intensity water exercise, J Physiol Anthropol 26(2): 179-183.

4) Wakabayashi H, Hanai A, Yokoyama S, Nomura T (2006) Thermal insulation and body temperature wearing a thermal swimsuit during water immersion, J Physiol Anthropol 25(5): 331-338.

5) Wakabayashi H, Hanai A, Kaneda K, Yokoyama S, Nomura T (2005) Effects of thermal swimsuit on thermoregulatory responses during light to moderate intensity exercise at cool water environment. In: Holmer I, Kuklane K and Gao C (Eds.) Environmental Ergonomics XI, Ystad, Sweden, 546-549.

Teaching the evidence base for aquatic therapy in persons with chronic disabilities

Daniel Daly[1], Johan Lambeck[1]

[1]Department of Rehabilitation Sciences, Katholieke Universiteit Leuven, Belgium

A Masters level intensive course reviews the evidence base for aquatic therapy in specific populations of persons with chronic disabilities. Specialized staff discuss concept and goal setting in aquatic therapy. Systematic Reviewing is taught including a) designing a search strategy: defining Population, Intervention, Comparisons and Outcome measures based on International Classification of Functioning (ICF) terminology. b) where to search: Pedro, Cochrane,…c) Critical Appraisal Systems: Delphi, SIGN, d) Reporting in written and oral form: (peer instruction). The economic (cost/benefit) implications of aquatic therapy are also examined. The participant obtains a good overview of the research base for aquatic therapy in the goal populations, should be able to perform a systematic review of a research article, classify the evidence and consult in a treatment team in developing aquatic therapy programmes for diverse individuals.

The course meets a specific need in Europe within the area of long term rehabilitation. Although aquatic therapy is widely used, European wide guidelines and best practices are only in the beginning stages of development and there is limited information available on groups and institutions using aquatic therapy, on specific facilities available, promotional programs, and specific academic courses.

Key words: *Aquatic therapy, Education, Systematic reviewing*

Activity in water or aquatic therapy[(1)] has decided advantages for persons with health-related problems resulting in impairments, activity limitations, and participation restrictions[1]. Water based activity is said to aid in the relief of pain and muscle spasm, maintain or increase range of motion, strengthen and re-educate weak and/or paralyzed muscles, improve circulation, lung function, and speech, and preserve and improve balance, co-ordination and posture. While aquatic therapy is particularly popular in dealing with e.g. Rheumatism and Orthopaedic problems[3], therapeutic activity in water

[(1)] **Aquatic therapy**: *Movement or exercise in an Aquatic (water) environment with an intended therapeutic outcome* (systematic exercise therapy during immersion in water resulting in a therapeutic outcome through stimulation of short and long-term adaptive (physiological) mechanisms in persons with a deranged biological system).

is also offered for persons with Stroke, spinal cord injury, Multiple Sclerosis, Parkinson disease and Cerebral Palsy[4].

Recreational as well as therapeutic activities are equally at home in water and all ages take part. A water based program provides excellent variety to an exercise program[5]. Aquatic facilities exist at or are used by numerous health care centres, major books have been published on rehabilitation in water and numerous courses are offered on "philosophies" of aquatic rehabilitation such as Halliwick, Bad Ragaz Ring Method, and Watsu. Nevertheless, in a 40 year review of rehabilitation literature on the use of aquatic therapy for children and adolescents with neuromuscular and musculoskeletal diagnoses, Getz et al.[6] state that most of the available articles are case reports and other descriptions of clinical practice with the notable exception of Rheumatology and Orthopaedics[7].

Aquatic therapy includes a large hands-on component, especially in neurological and paediatric rehabilitation. In these populations treatment is varied and complex, and aquatic therapy is usually only a minor component. Nonetheless, this might have an important place in long term rehabilitation where the effect of any treatment is smaller in measurable terms. Quantifying the effect of aquatic therapy has, as a consequence, not gained sufficient attention. The following statement recently found in the British Medical Journal[8] might best summarize the situation.

> In several European countries, balneotherapy and spa therapy are common treatments for low back pain. Although they are expensive, the costs are sometimes reimbursed by health insurance systems. A systematic review of these treatments found only five randomised controlled trials. Judged by self reported pain on a visual analogue scale, the treatments were modestly effective (*Rheumatology 2006;45: 880-4*). *But sceptics may agree that a more important finding is the mismatch between the popularity of these interventions and the paucity of evaluations of their efficacy.*

Water has an attraction of its own and swimming itself is a popular activity inducing self management and adherence. In the age of evidence based practice it seems appropriate to ask the question "What exactly is the outcome of systematic aquatic therapy for persons with disabilities?" Does aquatic therapy improve function, prevent regression of function? Might the persons who can perform little other activity independently “feel better” resulting in an increased quality of life despite no quantifiable physical changes?

Course organisation and content

In a 2 week Master level intensive course the evidence base for aquatic therapy in selected (Cardiovascular, Neuromuscular, Rheumatologic, Respiratory and Orthopaedic) diseases and disabilities has been reviewed in the range of geriatric to paediatric populations. Nine European partner Universities are involved and 3 students per partner are funded nearly in full (travel, room and board) to attend. Students are registered and pay their normal fees at the home institution and can receive credit by completing the course and additional credit for delivering a post course paper in ready to submit form. Non-partner students and young working professionals also attend for a fee providing a good mix of practical background and cultural diversity. The student profile can be described as allied health professionals who are completing the final degree needed to enter the profession and those specialized in aquatic therapy. In 2007, 12 partner institution staff members taught during the 2 week period. A number of non-partner experts also taught and additional local expertise is available to provide tutoring and expert evaluation of student presentations and reports.

The program includes the following points:

1. Concepts and goals setting in aquatic therapy in the population in question.
2. Systematic Reviewing: including a) designing a search strategy: defining Population, Intervention, Comparisons and Outcome measures based on ICF terminology. b) where to search: PEDro, Cochrane,…c) Critical Appraisal Tools: Delphi, SIGN, d) Reporting results in written and oral form: (peer instruction).
3. The economic (cost/benefit) implications of aquatic therapy.

The course is divided into mini-modules each dealing with one population based on the points above. Time is devoted to a refresher of the Cochrane systematic literature review strategy and overview of research methodological techniques. One of the most important aspects of the course is the student presentations made during the final days of the course. Groups of 3 students are assigned a topic on day 2 with the presentation planned for day 12 & 13. They work with the help of staff to systematically collect literature, perform methodological assessment and summarize the evidence on a particular topic such as aquatic therapy for low back pain. Students then make a 90 minute presentations (40 minutes presentation with 45min discussion with staff and students) in English although for most this is not the mother language. This peer instructional learning experience provides students with formal knowledge beyond their own presentation and the discussion period serves to clear up obvious knowledge gaps e.g. in statistics. Learning outcomes of such a European educational course furthermore go beyond the technical knowledge of Aquatic therapy or systematic reviewing.

The course participant therefore receives a good quality overview of the research base for aquatic therapy in the goal populations. They are then able to: a) Perform a systematic review of a research article and classify the evidence. b) Consult in a treatment team on the advisability of the use of aquatic therapy for individuals from diverse populations. Via a specific interest in aquatic therapy future professionals are made familiar with evidence based practice.

Some present findings and points for the future.

During the July 2007 course 6 student presentations were given on the effects of (active) aquatic therapy on Low Back Pain (LBP), Fibromyalgia, Osteoarthritis, Chronic Obstructive Pulmonary Disease, Rheumatoid Arthritis and in Neurology. The low back pain student review has been further developed and will be taken here as an example[9] and discussed in relation to a published review on spa treatment and balneotherapy for persons with LBP[10].

The students first searched PEDro, CINAHL (Ovid), PubMed, Cochrane controlled trial register and SPORTDiscus databases to identify relevant studies published between 1997-2007. Thirty five trials were found and 7 were accepted into the review. In 6 of the trials active aquatic therapy had a positive effect on pain and function in LBP. Outcome measures included the Oswestry low back pain disability questionnaire, the McGill pain questionnaire, subjective assessment scale for pain (e.g. Visual Analogue Scale (VAS)) and number of work days lost as a direct result of LBP. Active aquatic therapy was not, however, found to be better than other dry land based treatment. No adverse effects were found from any water based treatment. Methodological quality was considered low in all included studies using the SIGN 50 (Scottish Intercollegiate Guidelines Network) checklists for either Random Control Trials[11] or Case Control Trials[12]. There was large variation among studies in numbers of subjects, symptoms durations, interventions and outcome measures precluding a Meta analysis of the results. Therefore there is further need for high quality trails in which symptoms groups and interventions are better controlled, in which standardized outcome measures are used and which include follow-up evaluation.

Likewise in a study of Spa therapy and Balneotherapy (passive) for treating LBP[10], 60 studies were initially identified from the search, 10 were selected for further evaluation from which 5 were dropped not being reported as randomized. The results suggested significant differences in favour of spa therapy (3 studies) or balneotherapy (2 studies) as compared to waiting list controls using the VAS for pain. Here again no adverse effects were found. So both active and passive therapy appear to help reduce LBP without any adverse effects.

In conclusion, a number of points need to be emphasised. The outcome measures used in all 12 studies reviewed are not related to the cause of LBP but only to the result (pain, lost work days). Furthermore long term follow-up measurement was never seen in these studies and the drop out rates are not clearly given or were 0. As a result one does not know which of the treatments the patients may have preferred and might be more willing to adhere to. Economic factors are only mentioned concerning the high expense of spa and balneotherapy suggesting that this is not a feasible long term treatment.

Concepts and ideas on aquatic therapy vary from country to country. The type of educational undertaken described here allows for cross cultural exchange of ideas on the topic at hand. It also allows quick updates and changes in themes according to the needs of the time. In the future is will be important not to limit the project to literature collection and systematic review but to set up intervention studies to answer the questions being posed in the course and give young researchers the chance for further development.

REFERENCES

1. World Health Organisation (2001). ICF:International Classification of Functioning, Disability and Health. Geneva:World Health Organisation (CD-Rom).
2. Cole A. Becker B. (Eds) (2004). Comprehensive aquatic therapy, Philadelphia:Elsevier.
3. Franssens M, Nairn L, Winstanley J, Lam P, Edmonds J. (2007). Physical Activity for Osteoarthritis Management: A randomized controlled clinical trail evaluating

hydrotherapy or Tai Chi Classes. Arthritis & Rheumatism, 57(3): 407-414.

4. Daly D, Lambeck J. (2007). New Trends in Adapted Swimming. In Arellano R, Sanchez AJ, Navarro F, Morales E, Lopez G (ed). Swimming Science I. Granada, Editorial Universidad de Granada, 7-18.
5. Gowans SE, deHueck A, Voss S, Richardson M. (1999). A Randomized, Controlled Trial of Exercise and Education for Individuals with Fibromyalgia, Arthritis Care Research, 12(2):120-128.
6. Getz M, Hutzler Y, Vermeer A. (2006). Effects of aquatic interventions in children with neuromotor impairments: a systematic review of the literature. Clinical Rehabilitation, 20(11):927-36.
7. Geytenbeek J. (2002). Evidence for effective aquatic therapy. Physiotherapy. 88, 9:514-529.
8. British Medical Journal (2006). Minerva: 333:208.
9. Waller B, Lambeck J, Daly D. (2008). Active aquatic exercise in the treatment of Low Back Pain: A systematic review (in press).
10. Pittler MH, Karagülle MZ, Karagülle M, Ernst E. (2006). Spa therapy and Balneotherapy for treating low back pain: meta-analysis of randomized trials. Rheumatology, 45(7):880-4.
11. SIGN 50 RCT checklist. 2004. Accessed 7.07.2007. http://www.sign.ac.uk/guidelines/fulltext/50/checklist2.html
12. SIGN 50 CCT checklist. 2004. Accessed 7.07.2007. http://www.sign.ac.uk/guidelines/fulltext/50/checklist4.html

Acknowledgement

Parts of this work were made possible by the financial assistance of the ERASMUS IP Grant Agreement nr 2006-2151/001-001 SO2-21CIEU; Pr. Nr: 27945-IC-1-2005-1-BE-ERASMUS-IPUCœ6 and the CERA Foundation. Special thanks go to all the persons who come to our swimming pool each week.

Comparison of Walking Cycle of Underwater Walking and Land Walking in Elderly Women

Tomoki Shono[1], Kenji Masumoto[2], Kazutaka Fujishima[2], Noboru Hotta[2], Tetsuro Ogaki[2], Takahiro Adachi[3]

[1] Kyushu University of Health and Welfare, Japan

[2] Institute of Health Science, Kyushu University, Japan

[3] Center for Health and Sports Science, Kyushu Sangyo University, Japan

This study compared the walking cycle and physiological response of elderly persons during underwater walking and land walking. Seven healthy female volunteers (mean age 62.6 ± 4.0 years) participated in the study. Underwater walking was performed using a device with a treadmill placed at the base of a water flume. The simultaneous belt and water-flow velocity was varied at 20, 30, and 40 $m \cdot min^{-1}$. Water depth was at the level of the xiphoid process of each subject. Water temperature was 30.6 ± 0.1ºC. Land walking was performed on a treadmill at 40, 60, and 80 $m \cdot min^{-1}$. The results showed that the rate of the swing phase increased during underwater walking and the rates of the stance and double-support phases decreased in comparison with land walking at the same velocity and with the same oxygen uptake level. Furthermore, it was shown that underwater walking could be accomplished with lower stride frequency than land walking. The changes observed in the walking cycle during underwater walking suggest the effectiveness of this form of exercise, and it could contribute to prescribing exercise programs for elderly and people with low levels of physical fitness and for devising rehabilitation programs.

Key words: *walking cycle, underwater walking, land walking, elderly women*

INTRODUCTION

Underwater walking can be practiced without having swimming skill and it is an easy, nonswimming, aerobic activity for middle-aged and elderly people who wish to begin underwater exercises. Many previous studies have reported metabolic and cardiorespiratory responses during underwater walking (3, 5, 6). However, there is very little kinematic research regarding underwater walking (1, 2, 4) and none to date involving the elderly. Since it is difficult to fix the workload of walking in a pool, various studies for underwater walking have been carried out using devices for underwater walking (6). The device used in the present study, called a Flowmill, has a treadmill at the base of a water flume. Cardiorespiratory responses during walking in the Flowmill are very similar to those during walking in a pool (3). However, there it remains unclear whether cardiorespiratory responses correspond to parameters of the walking cycle during Flowmill walking. The purpose of this study, therefore, was to examine the relation between cardiorespiratory responses and parameters of the walking cycle during underwater walking in elderly women.

METHODS

Seven healthy female volunteers were recruited as subjects. All belonged to the same sports club and regularly swam and exercised in water. Mean age, height, weight and body-fat level were 62.6 ± 4.0 y, 154.9 ± 2.2 cm, 57.5 ± 6.8 kg, and 24.3 ± 6.0 %, respectively. This study was approved by the Ethics Committee of the Institute of Health Science, Kyushu University. Each subject gave written informed consent to participate.

Underwater walking was performed in the Flowmill (FM1200D, Japan Aqua Tech Co., Ltd., Japan), which has a treadmill at the base of a water flume. Each subject completed three consecutive rounds of walking for 4 minutes per round, each at a progressively increasing belt and water-flow velocity (20, 30 and 40 $m \cdot min^{-1}$), with a 1-minute rest interval after both the first and second rounds. Water depth was at the level of the xiphoid process of each subject. Water temperature was 30.6 ± 0.1ºC. Land walking was performed on a treadmill (WOODWAY, Sakai Co., Ltd., Japan). A previous study (3) reported that approximately double the velocity was needed to walk on the treadmill in order to obtain the same level of physiological effort as during Flowmill walking. Thus, the velocity of the treadmill in this study was double that of the Flowmill (40, 60 and 80 $m \cdot min^{-1}$), and grade of the treadmill was 0%. Room temperature and relative humidity were 24.8 ± 0.3 ºC and 54.9 ± 3.9%, respectively.

Oxygen uptake ($\dot{V}O_2$) was measured by a mass spectrometer (WSMR-1400, WESTRON

CORP., Japan) and an automatic breath-by-breath gas-exchange measurement system (RM-300i, Minato Medical Science Co., Ltd., Japan). Heart rate (HR) was monitored by telemetry (ST-30, DS-501, Fukuda-denshi Co., Ltd., Japan). Walking motion was recorded on videotape (DCR-TRV20, SONY, Japan). Time durations during one stride cycle, stance phase, double-support phase and swing phase, and stride frequency were calculated using two-dimensional motion analysis software (2DMADT Ver 3.0, Neuro-science Co., Ltd., Japan).

All data were analyzed by repeated-measures ANOVA. The post-hoc Scheffe test was used to determine statistical difference. Significance was established at the $p<0.05$ level.

RESULTS AND DISCUSSION

At the same velocity (40 m·min^{-1}), the time duration of one stride cycle during underwater walking was longer than during land walking (Table 1), and thus stride frequency during underwater walking was lower than during land walking. The time duration of the stance and swing phases during underwater walking were significantly longer than during land walking, whereas it was significantly shorter during the double-support phase during underwater walking. The reason for the shorter double-support phase during underwater walking could be attributable to the forward-bent posture assumed during underwater

Table 1. Mean values and standard deviation (S.D.) of all variables.

Variables	Walking condition	Mean	S.D.
Oxygen uptake (ml·kg^{-1}·min^{-1})	20 m·min^{-1} in water	7.3	1.3 ##††§§
	30 m·min^{-1} in water	10.4	1.5 §§
	40 m·min^{-1} in water	16.1	2.5 ##††
	40 m·min^{-1} on land	10.9	2.1
	60 m·min^{-1} on land	12.0	1.9
	80 m·min^{-1} on land	14.7	2.4
Heart rate (beats·min^{-1})	20 m·min^{-1} in water	79	8 ##††§§
	30 m·min^{-1} in water	88	9 §§
	40 m·min^{-1} in water	108	11 ##††
	40 m·min^{-1} on land	89	8
	60 m·min^{-1} on land	94	11
	80 m·min^{-1} on land	104	12
Time duration during one stride cycle (msec)	20 m·min^{-1} in water	2533	278 ##††§§
	30 m·min^{-1} in water	2116	351 ##††§§
	40 m·min^{-1} in water	1850	285 ##††§§
	40 m·min^{-1} on land	1195	39
	60 m·min^{-1} on land	1067	76
	80 m·min^{-1} on land	972	90
Time duration during stance phase (msec)	20 m·min^{-1} in water	1539	183 ##††§§
	30 m·min^{-1} in water	1228	153 ##††§§
	40 m·min^{-1} in water	1056	147 #††§§
	40 m·min^{-1} on land	806	25
	60 m·min^{-1} on land	683	46
	80 m·min^{-1} on land	600	56
Time duration during double-support phase (msec)	20 m·min^{-1} in water	555	131 #††§§
	30 m·min^{-1} in water	361	102
	40 m·min^{-1} in water	217	41 ##
	40 m·min^{-1} on land	400	0
	60 m·min^{-1} on land	306	39
	80 m·min^{-1} on land	233	36
Time duration during swing phase (msec)	20 m·min^{-1} in water	994	146 ##††§§
	30 m·min^{-1} in water	889	216 ##††§§
	40 m·min^{-1} in water	794	144 ##††§§
	40 m·min^{-1} on land	389	34
	60 m·min^{-1} on land	383	41
	80 m·min^{-1} on land	372	39
Stride frequency (strides·min^{-1})	20 m·min^{-1} in water	23.9	2.7 ##††§§
	30 m·min^{-1} in water	29.0	5.0 ##††§§
	40 m·min^{-1} in water	33.0	4.3 ##††§§
	40 m·min^{-1} on land	50.3	1.7
	60 m·min^{-1} on land	56.5	4.0
	80 m·min^{-1} on land	62.2	5.9

# $p<0.05$ vs. 40 m·min^{-1} on land, ## $p<0.01$ vs. 40 m·min^{-1} on land
†† $p<0.01$ vs. 60 m·min^{-1} on land
§§ $p<0.01$ vs. 80 m·min^{-1} on land

Table 2. Rate of each phase in one stride cycle under each walking condition.

Phase	Walking condition	Mean	S.D.
Stance phase (%)	20 $m \cdot min^{-1}$ in water	60.8	3.6 ##
	30 $m \cdot min^{-1}$ in water	58.4	4.2 ##†
	40 $m \cdot min^{-1}$ in water	57.2	1.9 ##†
	40 $m \cdot min^{-1}$ on land	67.5	2.2
	60 $m \cdot min^{-1}$ on land	64.1	2.1
	80 $m \cdot min^{-1}$ on land	61.7	1.3
Double-support phase (%)	20 $m \cdot min^{-1}$ in water	22.2	6.2 ##
	30 $m \cdot min^{-1}$ in water	17.5	5.9 ##††
	40 $m \cdot min^{-1}$ in water	12.0	3.2 ##††§§
	40 $m \cdot min^{-1}$ on land	33.5	1.1
	60 $m \cdot min^{-1}$ on land	28.8	3.9
	80 $m \cdot min^{-1}$ on land	23.9	2.1
Swing phase (%)	20 $m \cdot min^{-1}$ in water	39.2	3.6 ##
	30 $m \cdot min^{-1}$ in water	41.6	4.2 ##†
	40 $m \cdot min^{-1}$ in water	42.8	1.9 ##††
	40 $m \cdot min^{-1}$ on land	32.5	2.2
	60 $m \cdot min^{-1}$ on land	35.9	2.1
	80 $m \cdot min^{-1}$ on land	38.3	1.3

$p < 0.01$ vs. 40 $m \cdot min^{-1}$ on land
† $p < 0.05$ vs. 60 $m \cdot min^{-1}$ on land, †† $p < 0.01$ vs. 60 $m \cdot min^{-1}$ on land
§§ $p < 0.01$ vs. 80 $m \cdot min^{-1}$ on land

walking, and the reduced weight load to a single leg during the stance phase due to buoyancy. Thus, the shift of body weight to a forward leg may occur earlier than during land walking. The peak value corresponding to braking force during the stance phase on land does not appear in water; instead the driving force propelling the body forward in water appears throughout the stance phase (4). Therefore, it is considered that the influence of water resistance cannot be disregarded. In other words, the braking phase is omitted for the forward leg due to water resistance, and could therefore produce the driving force required to propel the body forward immediately after heel contact. Thus, it is considered that transfer to the forward leg begins early during underwater walking. The rates of the stance and double-support phases during underwater walking were significantly lower than during land walking (Table 2), whereas the rate of swing phase was significant higher.

At the same $\dot{V}O_2$ level, stride frequency during underwater walking was almost half that observed on land. This finding shows that gait velocity and gait movement in water are slow compared with land walking at the same exercise intensity level. The rate of the stance phase in one stride cycle during underwater walking was a little lower than during land walking (Figure 1). The rate of the swing phase in one stride cycle during underwater walking was a little higher than during land walking. The reason for this is that the rate of the double-support phase in one stride cycle during underwater walking was at almost half that observed on land and is likely caused by a forward-bent posture during underwater walking and the influences of buoyancy and water resistance. The rate of the double-support phase during underwater walking at each set velocity was significantly lower than land walking at each set velocity.

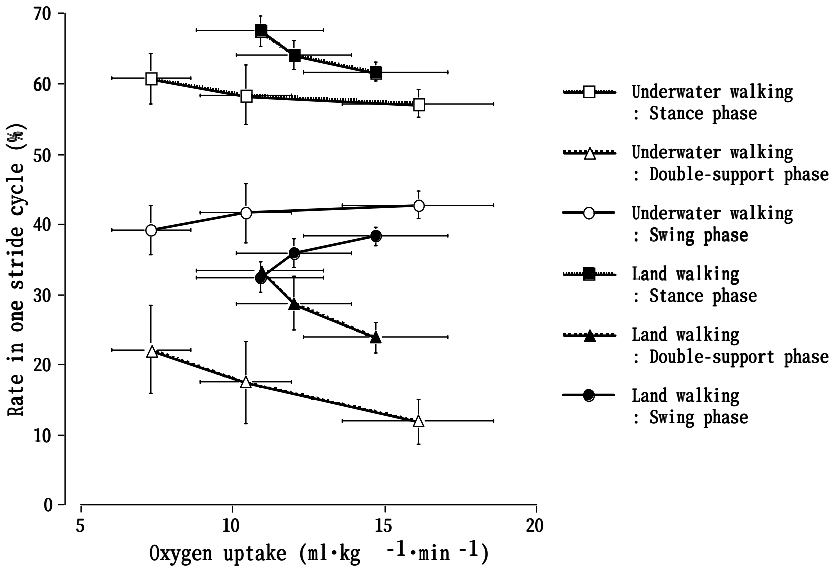


Figure 1. Relationship between oxygen uptake and rate of each phase in one stride cycle.

During land walking in the elderly, the rate of the swing phase decreased, and the rates of stance and double-support phases increased due to a decline in leg muscle strength associated with aging. For young males, the rate of the stance and swing phases in one stride cycle during underwater walking in a swimming pool were compared to the same exercise on a land treadmill at equivalent velocities (0.4, 0.6 and 0.8 $m \cdot s^{-1}$) (1, 2), and when these results are compared with those of the present study involving elderly women, velocities differed slightly in that the rate of stance phase in elderly women was slightly higher. It is likely that the rates of the stance and double-support phases increase with aging. During land walking at the same velocity, the elderly had a shorter step length, higher step frequency and shorter time duration during one stride cycle compared to that of the young males (1, 2). In water, however, the rate and time duration during one step cycle among the elderly women in the present study were almost same that of the young males. This finding suggests that the elderly can walk in a gait cycle very similar to that of the young in water, although a change of gait cycle is observed with aging on land.

CONCLUSION

The results of the present study showed that elderly women during underwater walking have lower stride frequency, higher rate of swing phase, and lower rates of stance and double-support phases than during land walking at the same set velocity and the same $\dot{V}O_2$ level. A biped walk is performed through complicated adjustments of the nervous and muscular systems. Underwater a complex water flow occurs due to waking and currents that disturb posture impact the body from every direction. Utility as training to keep body balance is suggested by various stimulation by walking underwater and there being time corresponding to the stimulation. It may act in particular advantageously that the rate of single support phase increases in one stride cycle.

Note: This paper was previously published in Japanese by the Japanese Journal of Health Promotion Vol.6 (2004). The Japan Society of Health Promotion has granted permission to submit a reworded version of the English paper to an international journal for wider dissemination of the contents.

REFERENCES

1. Kato T, Fukuzawa S, Sugajima Y, Kitagawa K (2002) Characteristics of underwater walking using water flow machine -Comparison of swimming pool walking with land treadmill walking-. Jpn. J. Phys. Fitness Sports Med. 51: 119-128 [In Japanese]
2. Kato, T., Sugajima, Y., Koeda, M., Fukuzawa, S., Kitagawa, K. (2002) Electromyogram activity of leg muscles during different types of underwater walking. Adv. Exerc. Sports Physiol., 8, 39-44.
3. Migita T, Muraoka Y, Hotta N, Ogaki T, Kanaya S, Fujishima K, Masuda T (1994) Cardiorespiratory responses during water and land walking. Kurume Journal of Health & Physical Education 2: 25-30 [in Japanese]
4. Miyoshi T, Tanizaki M, Satoh T, Komeda T, Yamamoto H, Nakazawa K, Yano H (2001) Ground reaction force during walking in water. JJBSE 5: 86-89 [In Japanese]
5. Shono, T., Fujishima, K., Hotta, N., Ogaki, T., Masumoto, K. (2001) Cardiorespiratory response to low-intensity walking in water and on land in elderly women. J. Physiol. Anthropol., 20, 269-274.
6. Shono T, Hotta N, Ogaki T, Fujishima K (2002) Physiological responses during water walking. Japanese Journal of Health Promotion 4: 1-10 [In Japanese]

Effects of aquatic exercise in different water depth on arterial stiffness

Akira YOSHIOKA [1], Yoko NAKADA [2], Kazuki NISHIMURA [1] , Michael KREMENIK [2] Sho ONODERA [2]

[1] Graduate School, Kawasaki University of Medical Welfare, health science, JAPAN

[2] Kawasaki University of Medical Welfare, health and sports science, JAPAN

We investigated whether the pulse wave velocity was influenced by aerobic exercise in water. Seven healthy males participated in this voluntary sturdy. Every subjects performed aerobic exercise on land (control) and in water for 30 minutes while watching a televised instructor after rest three times. Aerobic exercises in water were performed under two conditions, which were water at a depth of 110cm (W-110) and 150cm (W-150). We measured brachial – ankle pulse wave velocity (baPWV) before and after 30 minutes of exercise. The baPWV after the exercise was significantly lower than before exercise at 110-W ($P<0.05$). At the other condition, however, the baPWV showed no change. These data suggest that effects of exercise in water on arterial stiffness vary from water depth, and the improvement of PWV depends on not only exercise intensity but also water depth.

Keywords : *arterial stiffness, pulse wave velocity, aerobic exercise in water, water depth*

INTRODUCTION

Many people in the fields of health promotion, rehabilitation and so on have performed exercises in water, which have physical characteristics. There are many reports about effects of aquatic exercise. However, there have been few reports about effects of aquatic exercise on the vascular system. Recently, there have been many reports that induce functionally and morphologically changes of the vascular system by performing the exercise on land. Pulse wave velocity (PWV), which is an index of arterial stiffness, was decreased by aerobic exercise at low intensity[1]. We hypothesized that PWV was also improved by performing the aerobic exercise in water, as well as the exercise on land. We investigated whether the pulse wave velocity was influenced by aerobic exercise in water.

METHODS

Seven healthy young males volunteered to participate in this sturdy. All subjects signed an informed consent form prior to participation in this study. The subjects had a mean age 24.6 (SD 1.5) years, mean height 170.3 (SD 5.4) cm, mean body mass 68.5 (SD 8.7) kg, and mean % body fat 19.2 (SD 5.3) %. Subjects performed aerobic exercise on land (control) and in water for 30 minutes while watching a televised instructor three times after rest in a standing position. Aerobic exercise in water was performed under two conditions, which were at a water depth of 110cm (W-110) and 150cm (W-150). The exercise consisted of including basal movement of aerobic exercise in water, which were jogging, walking, jumping, and so on, and the rhythms of exercise were 128 beats per minutes. Room temperature was 27.3 (SD 1.3) degrees Celsius, and water temperature was 30.4 (SD 1.1) degrees Celsius. We measured brachial – ankle pulse wave velocity (baPWV) using a volume-plethymographic apparatus (form PWV/ABI ;

Colin, co. ltd., Japan) before and 30 minutes after exercise. The subjects were examined in the supine position with electro cardiogram electrodes placed on both wrists, and cuffs wrapped on both the brachia and ankles (Fig.1). The baPWV were defined as mean value of baPWV calculated from right brachia and ankle, and that calculated from the other side in this study. Also, we measured heart rate (HR) throughout the experiment. Data are expressed as the mean ± SD. Paired t tests were used for comparison of baPWV and HR between pre and after exercise, and post-hoc tests were used for comparison of baPWV and HR between conditions. $P<0.05$ was considered significant.

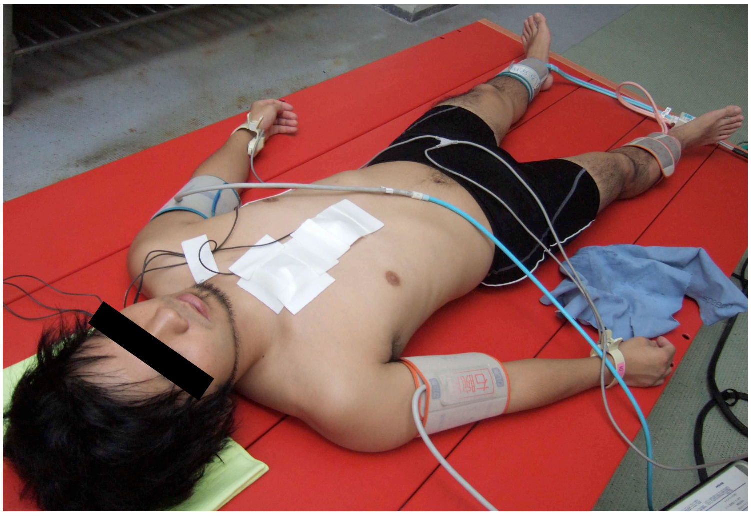
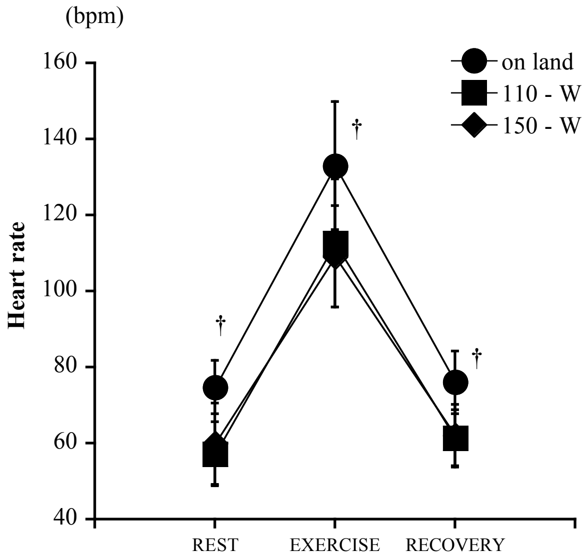


Figure 1. This picture is an example of a subject was measured baPWV.

RESULTS

At rest and during exercise and recovery, heart rate at control was significantly higher than water exercise conditions ($P<0.05$; Fig.2). HR at 30 minutes after exercise was higher than that of rest at control ($P<0.05$), but the other condition had no difference between pre and after exercise (Fig.3). The baPWV after exercise was significantly lower than before exercise at 110-W (P<0.05). At the other condition, however, the baPWV showed no change (Fig.4).



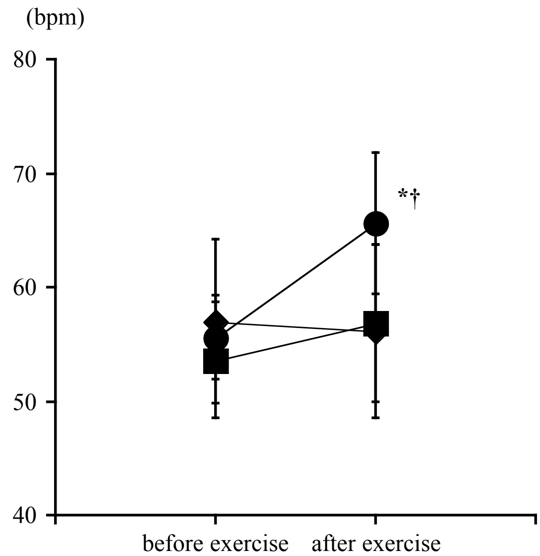


Figure 2. Changes in heart rate during the experiment. † P<0.05, vs the other conditions.

Figure 3. Changes in heart rate during the measurement of baPWV. * P<0.05, vs before exercise. † P<0.05, vs the other conditions.(right)

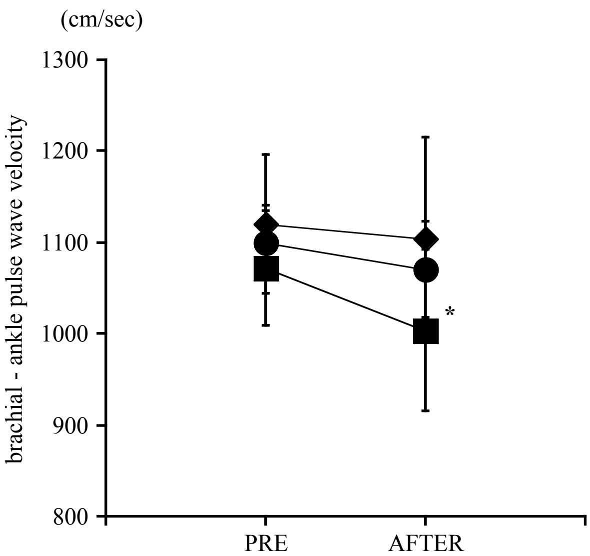


Figure 4. Changes in baPWV before and after exercise. * P<0.05, vs before exercise.

DISCUSSION

We investigated whether arterial stiffness was influenced by aerobic exercise in water. The baPWV after exercise was significantly lower than before exercise at 110-W. At the other condition, however, the baPWV showed no change. We did not observe the difference of HR during exercise between 110-W and 150-W in this study. However, the baPWV at 110-W decreased after exercise, but that of 150-W showed no change. These results showed the possibility that baPWV was affected by not only exercise but also physical characteristics of water. Moreover, the difference of baPWV after exercise between 110-W and 150-W might have been influenced by body temperature because a large part of body, especially the body trunk, was exposed to water at 150-W. However, it's mechanisms were unclear because we did not investigate body temperature in this study. In previous study, arterial stiffness of exercised leg was improved by acute low-intensity single-legged cycle ergometric exercise at 20-30W [1)]. However, baPWV in control showed no change in this study. Heart rate during exercise was 133.0 (SD 16.9) bpm in this study. These results showed that the intensity of exercise on land was moderate in this study. The intensity of exercise on land was relatively higher and might have affected autonomic nervous system activity by muscle metaboreflex. We suggested that to suppress the reduction of sympathetic nervous system activity inhibited to decrease PWV. However, PWV after exercise on land might have improved by extension of recovery times after exercise, because there has been a report that arterial stiffness was associated to aerobic capacity [2)].

CONCLUSION

These data suggested that arterial stiffness were also improved by water exercise. Moreover, effects of exercise in water on arterial stiffness vary from water depth, and the improvement of arterial stiffness depends on not only exercise intensity but also water depth.

REFERENCES

1.Sugawara J, Otsuki T, Tanabe T, Maeda S, Kuno S, Ajisaka R, Matsuda M (2003). The effects of low-intensity single-leg exercise on regional arterial stiffness. Jpn J Physiol, 53(3):239-41

2.Vaitkevicius PV, Fleg JL, Engel JH, O’Connor FC, Wright JG, Lakatta LE, Yin FC, Lakatta EG（1993）Effects of age and aerobic capacity on arterial stiffness in healthy adults. Circulation, 88(1):1,456-62.

Authors Index