View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by Northern Michigan University: The Commons

THE RELATIONSHIP BETWEEN TRUNK KINEMATIC VARIABLES AND UNDERWATER UNDULATORY SWIMMING PERFORMANCE IN COMPETITIVE SWIMMERS

Takahiro Tanaka[1] Takahiko Sato[2], Satoru Hashizume[2], Naruhiro Shiozawa[2] and Tadao Isaka[2]

Graduate School of Sports and Health Science, Ritsumeikan University, Shiga, Japan[1]
Faculty of Sports and Health Science, Ritsumeikan University, Shiga, Japan[2]

This study aimed to examine the relationship between the selected trunk kinematic variables and the undulatory underwater swimming performance in competitive swimmers. Eight male and 2 female swimmers performed 15 m undulatory underwater swimming with their maximum efforts. The range of motion and the corresponding angular velocity were computed for the chest, upper and lower waists by using the motion capture data. Significant correlations were found between the horizontal velocity of the center of mass and the angular velocity of lower waist and of chest, but not for between the corresponding horizontal velocity and every range of motions. These results suggest that the swimmers produce the great horizontal velocity by increase in trunk angular velocities rather than by increase in trunk range of motion.

KEYWORDS: swimming performance, trunk angle, trunk angular velocity

INTRODUCTION: The underwater undulatory swimming (UUS) is an underwater propelling technique used during the start and turn phases in competitive swimming, in particular freestyle, backstroke and butterfly stroke events. Previous study reported that the lap times of start and turn phases were positively correlated with total race time, indicating that the UUS is one of important technique to improve the swimming performance (Arrelano et al., 1994).
The trunk kinematic variables are thought to be associate with the velocity of body during the UUS. Previous study reported that the maximum chest flexion angle and the range of motion (ROM) of the trunk were correlated with the velocity of body during the UUS (Atkison et al., 2014). Further, simulation study reported that the large trunk undulatory motion induces increase in the velocity of body during the UUS (Nakashima, 2009). However, it remains unclear whether the trunk ROM associate with the body velocity during the UUS in competitive swimmers.
In the trunk kinematic variables, the angular velocity may be also important parameter to improve the body velocity during the UUS. The toe vertical velocity and kick frequency were also associate with the body velocity during the UUS (Higgs et al., 2017; Houel et al., 2013). Mechanically, the kinetic energy is transferred from the proximal body segments (i.e trunk) to the distal body segments (i.e feet), and this induces increase in the velocity of the distal segment during the UUS (Zamaparo et al., 2002). These suggest that the trunk angular velocity associate with the body velocity during the UUS, and however no studies are examined this relationship.
The purpose of this study, therefore, was to examine the relationship between the body velocity and the selected trunk kinematic variables during the USS in competitive swimmers. Based on the previous studies, we hypothesized that the larger trunk ROM and the angular velocity are correlated with the body velocity during the USS.

METHODS: Eight male (Age; 20.9±2.9 years old, Body mass; 67.8±5.0 kg, Height; 1.7±0.1 m) and 2 female (Age; 22.5±2.1 years old, Body mass; 54.3±7.4 kg, Height; 1.6±0.1 m) swimmers participated in this study. Their International Swimming Federation (FINA) points was 600.4±62.2. The experimental protocol was approved by the local ethical committee and was in accordance with the guidelines set out in the Declaration of Helsinki. All subjects gave written informed consent before participation. The underwater motion capture system with 8 cameras

(Qualysis, Sweden) was set at an indoor pool (7 lanes×25 m, depth; 1.35 m water temperature; 30 degrees). Before the data collection, 12 reflective markers were attached on the right anatomical landmarks (Atkison et al., 2014) (Fig. 2). All subjects were asked to perform the three trials of 15 m UUS with their maximum efforts with the wall-push start. Three-dimensional coordinate of markers were corrected during the UUS at 100Hz of sampling rate (Fig. 1).

The corrected data was smoothed by using the Butterworth low-pass filter with a cut-off frequency of 6Hz. The mean value of the horizontal velocity of center of mass (V_{com}) was determined by using the method proposed by Ae et al., (1992). The lower waist ($\theta_{lower\ waist}$), upper waist ($\theta_{upper\ waist}$) and chest (θ_{chest}) angles were defined as the relative angle between each proximal and distal segments projected onto the sagittal plane (Fig. 2). These data were temporally normalized from 0% to 100% of kicking motion. The ROM and the mean value of the absolute angular velocity were then determined for each angle. The relationships between the V_{com} and each trunk kinematic variables were evaluated using a Pearson's product moment correlation. Statistical significance was set at $p < 0.05$.

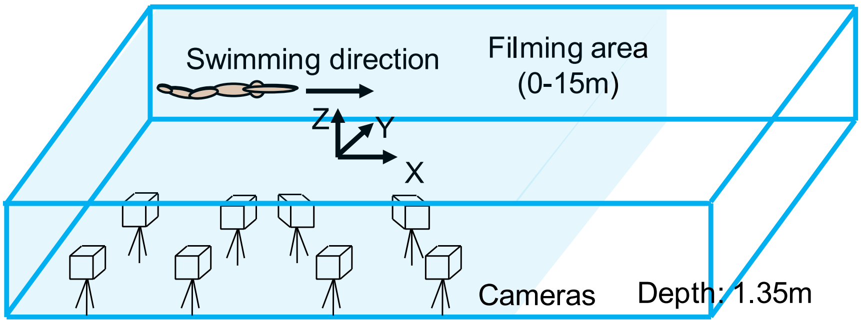

Figure 1: The experimental setting.

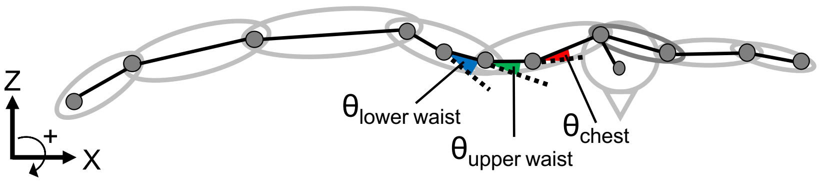

Figure 2: The whole body segment model used in this study. The anatomical landmarks were as follows; epiphysis of fifth metatarsal (toe), lateral malleolus (ankle), lateral epicondyle of the femur (knee), greater trochanter (hip), iliac horn (lower waist), lower end of the tenth rib (upper waist), xiphoid (chest), the tragus (ear), acromion (shoulder), lateral epicondyle of the humerus (elbow), styloid process (wrist) and tips of the third finger (finger). The definition of the angles at the lower waist ($\theta_{lower\ waist}$) (blue), upper waist ($\theta_{upper\ waist}$) (green) and chest (θ_{chest}) (red).

RESULTS: The Figure 3 revealed the time-history data of the V_{com}, the lower waist, upper waist and chest angles and the corresponding angular velocities during the UUS. There were no significant correlations between the V_{com} and each ROM (Table 1). The mean value of absolute angular velocity of the lower waist and chest were significantly correlated to the V_{com}, whereas no significant correlation was found between the V_{com} and the corresponding value of the upper waist (Table 1).

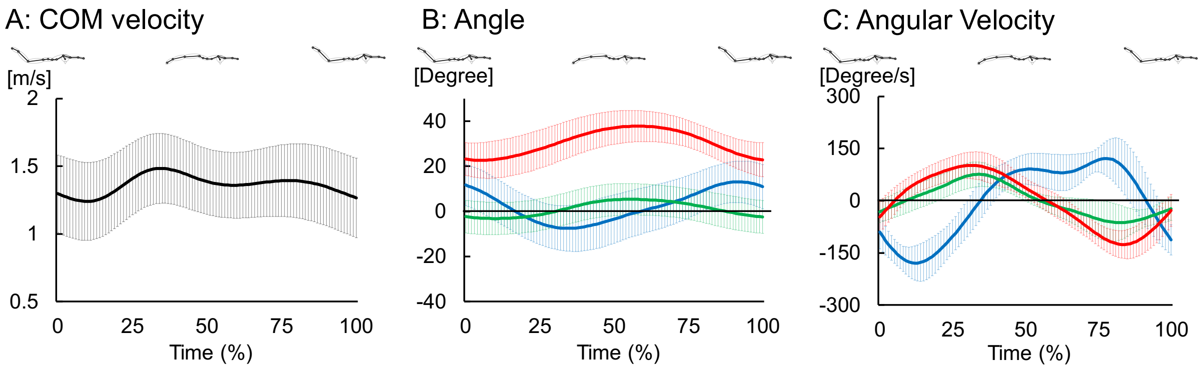

Figure 3: The time-history data of horizontal velocity of center of mass (A), trunk angles (B) and trunk angular velocities (C) during the UUS. The blue, green and red lines represent the data of lower waist, upper waist and chest, respectively. The positive and negative values indicate the extension and flexion, respectively.

Table 1: The results of a Pearson's product moment correlation between the V_{com} and each trunk kinematic variable.

		r value	p value
lower waist	ROM (deg)	0.360	0.306
	mean angular velocity (deg/s)	**0.700***	**0.024**
upper waist	ROM (deg)	0.411	0.237
	mean angular velocity (deg/s)	0.628	0.052
chest	ROM (deg)	0.421	0.226
	mean angular velocity (deg/s)	**0.727***	**0.017**

DISCUSSION: The purpose of this study was to examine the relationship between the body velocity and the selected trunk kinematic variables during the USS in competitive swimmers. As the results, no significant correlations were found between the V_{com} and each ROM. The V_{com} and the mean value of absolute angular velocity of upper waist was also not correlated, whereas the significant correlations were found between the V_{com} and the other two angular velocities. These results partly support our hypothesis.

There was no significant correlation between the V_{com} and each ROM (Table 1). Nakashima (2009) reported the conflict result that the great trunk undulatory movement induced increase in the V_{com} during the UUS. This simulation study (Nakashima 2009) controlled the magnitude of trunk undulatory movement for a given duration of the kicking motion, and therefore the change in trunk undulatory movement was equivalent to the change in the corresponding velocity. Meanwhile, in the current experimental study, the difference in trunk undulatory movement was not necessarily equal to the difference in the corresponding velocity. This may be the reason of the gap between the result of simulation study (Nakashima 2009) and the current result of experimental study using competitive swimmers.
There was no significant correlation between the V_{com} and the mean value of absolute angular velocity of upper waist, whereas the significant correlations were found between the V_{com} and the other two angular velocities (Table 1). The previous studies reported that the vertical toe velocity and kick frequency were positively correlated with the V_{com} (Higgs et al., 2017; Houel et al., 2013). The great angular velocities of the lower waist and chest could generate the great kinetic energy, and these were transferred to the distal body segments (Zamaparo et al., 2002). The transferred kinetic energy induces increase in the velocity of foot during the UUS. This may be the reason of the positive correlation between the V_{com} and the angular velocities of the lower waist and chest. The current results suggest that competitive swimmers may have potential to improve their performance by training to perform UUS using high frequency of trunk oscillation without decreasing the ROM.

CONCLUSION: The purpose of this study was to examine the relationship between the body velocity and the selected trunk kinematic variables during the USS in competitive swimmers. The main findings of this study were as follows: 1) no significant correlations were found between the V_{com} and each ROM, 2) the V_{com} and the mean value of absolute angular velocity of upper waist was also not correlated, whereas the significant correlations were found between the V_{com} and the other two angular velocities. The current results suggest that the competitive swimmers induce the great horizontal velocity by increase in trunk angular velocities rather than by increase in trunk range of motion.

REFERENCES

Ae, M., Tang, H. and Yokoi, T. (1992). Estimation of inertia properties of the body segments in Japanese athletes. *Biomechanism*, 11, 23-33.

Atkison, R.R., Dickey, J.P., Dragunas, A. and Nolte, V. (2014). Importance of sagittal kick symmetry for underwater dolphin kick performance. *Human Movement Science*, 33, 298-311.

Arellano, R., Brown, P., Cappaert, J. and Nelson, R.C. (1994). Analysis of 50-, 100-, and 200-m freestyle swimmers at the 1992 Olympic games. Journal of Applied Biomechanis, 10(2), 189-199.

Higgs, A.J., Pease, D.L. and Sanders, R.H. (2017). Relationships between kinematics and undulatory underwater swimming performance. *Journal of Sports Science*, 35(10), 995-1003.

Houel, N., Elipot, M., Andre, F. and Hellard, P. (2013). Influence of Angles of Attack, Frequency and Kick Amplitude on Swimmer’s Horizontal Velocity During Underwater Phase of a Grab Start. *Journal of Applied Biomechanics*, 29(1), 49-54.

Nakashima, M. (2009). Influence of angles of attack, frequency and kick amplitude on swimmer's horizontal velocity during underwater phase of a grab start. *Journal of Biomechanical Science and Engineering*, 4(1), 94-104.

Zamparo, P., Pendergast, D.R., Termin, B. and Minetti, A.E. (2002). How fins affect the economy and efficiency of human swimming. *The Journal of Experimental Biology*, 205, 2665-2676.