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Construction of a multiple-regression model for estimating the force in tethered swimming, and power in semi-tethered swimming for males

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Abstract

The purposes of this study were to clarify the relationship between the force in tethered swimming (TS) and the power in semi-tethered swimming (STS), and to develop multiple regression models to estimate the force in the TS and the power in the STS using plural physical elements. To perform these purposes, the force in the TS and the power in the STS of 53 elite male high school and junior high school swimmers as subjects were measured. The force in the TS was measured by an electrical digital force gauge. The power in the STS was measured by the ergometer attachment improved a bicycle ergometer. Furthermore, height(163.2cm in average), weight (51.6kg), finger reach span (168.4cm), foot length (26.1cm), vertical jump (43.0cm) and its power of each subject was measured. The results of this study were summarized as follows; 1) The relationships between the force in the TS (X) and the power in the STS (Y) was Y=0.182X+16.35 (r=0.814). This relationship was highly significant statistically (p<0.001). 2) 49 of the multiple regression models to estimate the force in the TS were derived. The highest correlation coefficient model in theses was as follows; TS=0.16×weight+0.75×age+0.03×finger reach span+1.10×foot length+0.22×vertical jump-41.68 (r=0.787). 3) 59 of the multiple regression models to estimate the power in the STS were derived. The highest correlation coefficient model in these was as follows; STS=0.03×height+0.45×weight+2.26×age+0.41×finger reach span+0.27×vertical jump+0.01×vertical jump power-88.56 (r=0.866).

Keywords: Force; tethered swimming; power; semi-tethered swimming; multiple regression model

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1. Introduction

The resisted swimming carried out in the competitive swimming training has 2 types. One type is fully-tethered swimming (TS) without swimming forward. Another type is semi-tethered swimming (STS) with swimming forward [1, 2]. Moritani et al. evaluated the swimming performance of Japanese elite swimmers using the STS [4]. Furthermore, they clarified the relationship between the STS and the rating of perceived exertion in swimming [5]. Shionoya et al. developed the ergometer attachment for measuring the power in the STS and reported the relationship between the swimming performance in sprint events and the power in the STS [3, 7]. On the other hand, concerning the TS, Shionoya et al. developed the system for measuring the force in the TS and reported the relationship between the swimming performance in sprint events and the force in the TS as in the STS case [8]. The relationship, however, between the power in the STS, the force in the TS and the physical capacity or the physique has not been clarified yet.

The purposes of this study were to clarify the relationship between the force in the TS and the power in the STS, and to develop the multiple regression models to estimate the force in the TS and the power in the STS using the plural physical elements.

2. Methods

Subjects were 53 elite male high school and junior high school swimmers designated to train by Niigata swimming association between 2004 from 2010. Figure 1(a) shows an overview for measuring the force in the TS. Each subject swum with pulling the wire connected to the digital force gauge (IMADA:DPX-50T). The force was measured by this digital force gauge. The output signal from the force gauge was transformed by an A/D converter to be analyzed by a kinetic analysis system (ELMEC: DAC-Win Ver4.7) installed into a personal computer. Figure 1(b) shows an overview for measuring the power in the STS. The Power was measured by the ergometer attachment installed the attachment drum coiling a wire, of which each swimmer pulled, onto one side of pedal of a bicycle ergometer. A bicycle ergometer equipping with an electrical magnetic breaking system (COMBI Corp. Power Max V) was used as a core of the ergometer attachment in this study. The power was calculated by the product of a velocity and a force. Figure 2(a) shows a calibration way of a velocity and a force in the ergometer attachment. In order to calibrate a velocity of the attachment drum, a digital tachometer was installed onto the side of drum. The velocity of the drum was equal to the swimming velocity. In order to calibrate the force loaded to a wire, the force calibration board used a digital force gauge was installed onto the

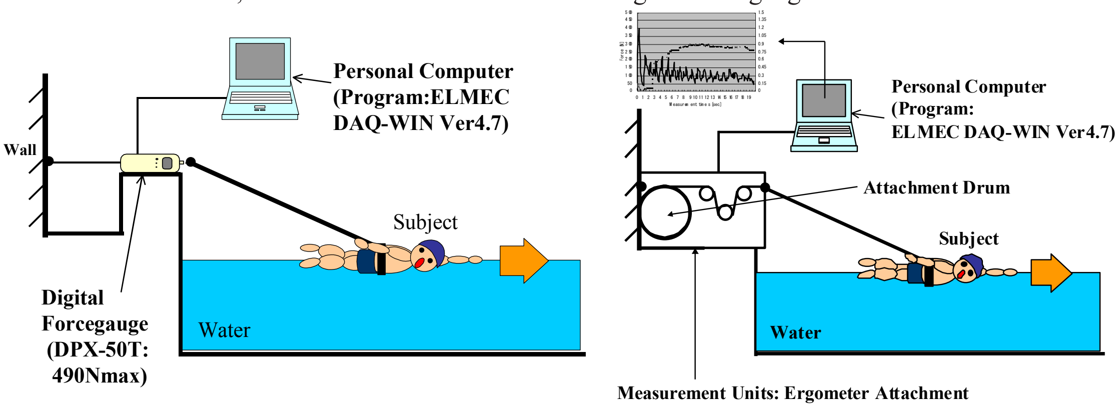


Fig.1. (a) Overview of the force in the TS measurement; (b) Overview of the power in the STS measurement

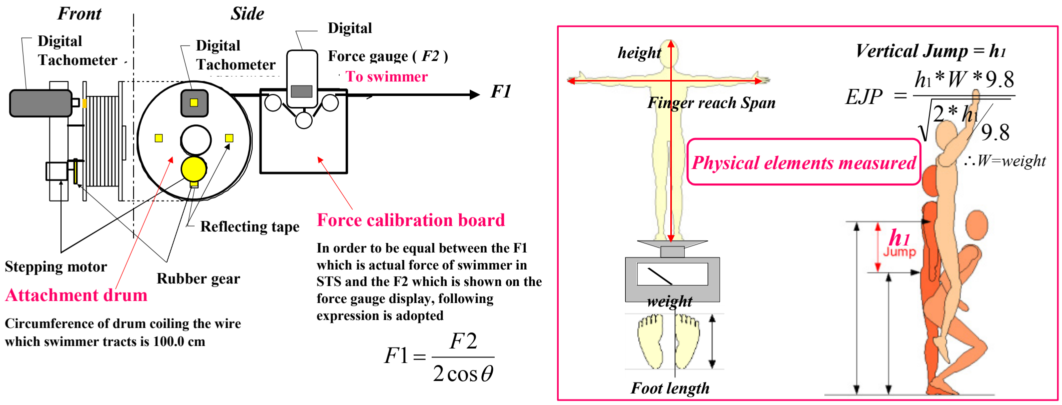


Fig. 2. (a) Calibration way of velocity and force using digital force gauge and tachometer; (b) Measurement of physical elements; height, weight finger reach span, foot length and vertical jump

ergometer attachment. The output signals from the tachometer and the force gauge were transformed by an A/D converter to be analyzed by a kinetic analysis system (ELMEC: DAC-Win Ver4.7) installed into a personal computer. Furthermore, a height, weight, finger reached span, foot length and vertical jump in each subject was measured (Figure 2(b)) as physical elements. The vertical jump power in each subject was calculated from the height of vertical jump using the following formula;

$$EJP = \frac{h1 * W * 9.8}{\sqrt{\frac{2 + h1}{9.8}}} \qquad (1)$$

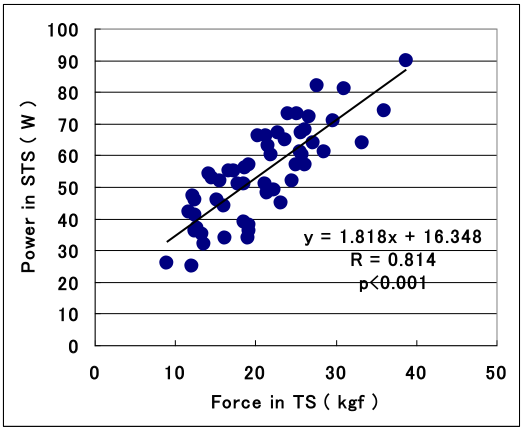
where h1 was a height of vertical jump, W was a weight, 9.8 was the acceleration of the gravity.

Based on these measurements, the relationship between the force in the TS and the power in the STS was clarified and the multiple regression models to estimate the force in the TS and the power in the STS with plural physical elements was developed.

3. Results and Discussions

Figure 3(a) shows the relationship between the force in the TS and the power in the STS. The relationship between the force in the TS (X) and the power in the STS (Y) was Y=1.82X+16.35, a correlation coefficient was 0.814 and this relationship was highly significant statistically ($p<0.001$).

Table 1 shows the correlation matrix between each element including the force in the TS and the power in the STS. The relationships between the force in the TS and all physical elements were significant statistically. Especially, the relationship between the force in the TS and the vertical jump power was highly significant ($r=0.750$). The relationship between the power in the STS and all physical elements were significant statistically again, too. Especially, the relationship between the power in the STS and the height, weight, finger reach span and vertical jump power were highly significant statistically. When the multiple-regression model, which estimated the force in the TS, was calculated by the multi-regression analysis, 49 models used elements from 3 to 5 were derived. Furthermore, when the multiple-regression model, which estimated the power in the STS, was calculated, 59 models used elements from 3 to 6 were derived. Table 2 shows the models, estimated the force in the TS, of which correlation coefficient were more than 0.770. The highest correlation coefficient model was TS = 0.16×weight +0.75×age + 0.03×finger reach span + 1.10×foot length + 0.22×vertical jump - 41.68 (r=0.787).



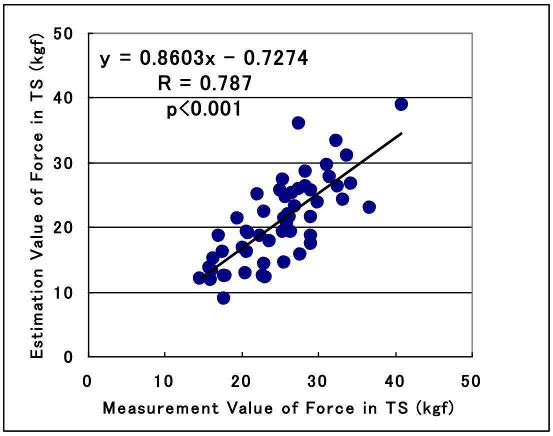


Fig 3. (a) Relationship between the force in TS and the power in the STS; (b) Relationship between the force estimated and the force measured in the TS

Table 1. Correlation matrix between each element.

	STS	TS	Height	Weight	Age	Finger span	Foot length	Vertical jump	Jump power
STS		0.814 ***	0.799 ***	0.785 ***	0.744 ***	0.780 ***	0.704 ***	0.559 ***	0.815 ***
TS	0.814 ***		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 **	0.835 ***
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, ***0.0001

Table 2. Multiple regression models for the force in the TS estimation (with more than of coefficient of correlation 0.770)

5 elements model
TS=0.16×weight+0.75×age+0.03×finger reach span+1.10×foot length+0.22×vertical jump-41.68 (r=0.787)
TS=0.76×age+0.03×finger reach span+1.10×foot length+0.13×vertical jump+0.01×vertical jump power-37.93 (r=0.786)
4 elements model
TS=0.26×weight+0.90×age+0.25×vertical jump+0.01×vertical jump power-16.89 (r=0.771)
3 elements model
TS=1.38×foot length+0.13×vertical jump+0.02×vertical jump power -32.63 (r=0.773)

Table 3. Multiple regression models for the power in the TS estimation (with more than of coefficient of correlation 0.860)

6 elements model
STS=0.43×height+0.31×weight+2.22×age+0.27×foot length+0.20×vertical jump+0.01×vertical jump power-88.52 (r=0.860)
STS=0.03×height+0.45×weight+2.26×age+0.41×finger reach span+0.27×vertical jump +0.01×vertical jump power-88.56 (r=0.866)
5 elements model
STS=0.05×height+0.23×age+0.40×finger reach span+0.01×vertical jump+0.03×vertical jump power-7790 (r=0.866)
STS=0.46×weight+2.29×age+0.43×finger reach span+0.27×vertical jump+0.01×vertical jump power-87.07 (r=0.866)
4 elements model
STS=0.04×weight+2.32×age+0.42×finger reach span+0.03×vertical jump power-58.18 (r=0.861)

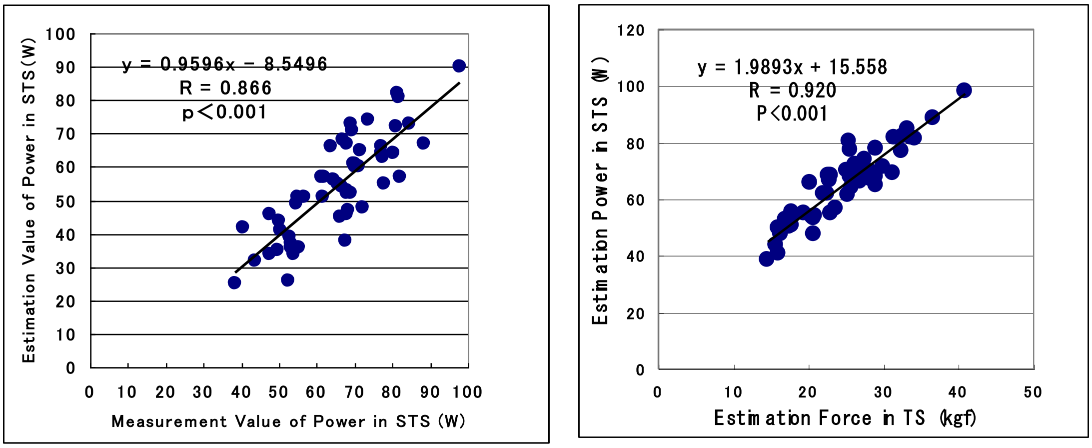


Fig 4. (a) Relationship between the power estimated and the power measured in the STS; (b) Relationship between the power estimated and the force measured

Table 3 shows the models, estimated the power in the STS, of which correlation coefficient were more than 0.861. The highest correlation coefficient model was STS = 0.03×height + 0.45×weight + 2.26×age

+ 0.41×finger reach span + 0.27×vertical jump + 0.01×vertical jump power - 88.56 ($r=0.866$). Figure 3(b) shows the relationship between the force in the TS estimated by the above mentioned 5 elements model (Y) and that measured (X). Both relationship was $Y=0.86X-0.73$ and this relationship was highly significant statistically ($p<0.001$). Figure 4(a) shows the relationship between the power in the STS estimated by the above mentioned 6 elements model (Y) and that measured (X) in this study. Both relationship was $Y=0.96X-8.55$ and this relationship was highly significant statistically as in the TS ($p<0.001$). Figure 4(b) shows the relationship between the power in the STS estimated by the above mentioned 6 elements model (Y) and the force in the TS (X) by the above mentioned 5 elements model. Both relationship was $Y=1.99X-15.56$ ($r=0.92$) and this relationship was highly significant statistically ($p<0.001$).

The multiple regression models for the force in the TS and the power in the STS estimation which this study provided could estimate in high correlation than these estimations from one element [6], and it is thought to be a useful model in estimating the force in the TS and the power in the STS from a physical element.

4. Conclusions

The conclusions from this study are that:

- The relationships between the force in the TS (X) and the power in the STS (Y) was $Y=0.182X+16.35$ ($r=0.814$). This relationship was highly significant statistically ($p<0.001$).
- 49 of the multiple regression models to estimate the force in the TS were derived. The highest correlation coefficient model was as follows; TS = 0.16×weight + 0.75×age + 0.03×finger reach span + 1.10×foot length + 0.22×vertical jump - 41.68 ($r=0.787$).
- 59 of the multiple regression models to estimate the power in the STS were derived. The highest correlation coefficient was as follows; STS = 0.03×height + 0.45×weight + 2.26×age + 0.41×finger reach span + 0.27×vertical jump + 0.01×vertical jump power - 88.56 ($r=0.866$)

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