Gender Difference of Aerobic Contribution to Surface Performances in Finswimming: Analysis Using the Critical Velocity Method

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Abstract

Purpose: **Finswimming is a speed competition sport practiced on the surface or underwater, by using monofins or two fins. In surface events (SF), competitors should surface within 15 m after the start and any turns. The aim of this study was to investigate the gender differences in the aerobic contribution to SF performances in finswimming, using the critical velocity (CV) concept in the analysis.**

Methods: **The participants were sixteen monofin swimmers (eight males and eight females; 24±6 years). During a two-day period, participants performed maximal effort swimming at five test distances (100 m, 200 m, 400 m, 800 m and 1500 m), and mean swimming velocity (V) of each distance was calculated . CV was calculated as the slope of the regression line between time and distance in the 400 and 800 m SF tests.**

Results: **Although CV was significantly correlated with V800 m and V1500 m for males, it was significantly correlated with V200 m, V400 m, V800 m and V1500 m for females.**

Conclusion: **The present results suggest that although the aerobic performance might contribute to SF performance for events from medium distance (i.e. 200m) to long distance (i.e. 1500m) in female participants, it might contribute to the long distance SF performances in male participants.**

Key Words: Finswimming; Monofin Swimming; Critical Velocity; Surface; Aerobic Contribution; Gender Difference

INTRODUCTION

Finswimming is a speed competition sport practiced at the surface or underwater with fins. Surface (SF) is a finswimming event, and it refers to progression with one monofin or with two fins on the surface. In swimming pools. Distances of 50, 100, 200, 400, 800 and 1500 m SF are recognized officially by the World Underwater Federation [1]. The male world records in 50 and 1500 m SF are 15.20 s and 12 min 13.52 s as of 1st, January, 2013.

A linear relation is observed between the maximum work and the maximum time in which the work was been performed until the onset of local muscular exhaustion [2]. The slope of the linear regression line is referred to as the critical power (CP), and it is defined theoretically as the highest power attainable during exercise without exhaustion [2]. The CP concept has been applied to a wide range of endurance sports such as cycling (including bicycle ergometer) [2-6], running [7-9] and rowing [10]. In swimming, Wakayoshi et al. [11] have applied the CP concept to competitive swimming as the critical velocity (CV). It was expressed as the slope of the linear regression line between swimming different distances (D) and the fastest time (T) [11-15]. The regression analysis of D and T showed extremely high linearity and CV was defined as the swimming speed that can theoretically be maintained for a very long time without exhaustion. Furthermore, CV is a useful index for aerobic performance because it shows

a positive correlation between itself and the LT (lactate threshold) [14], OBLA (onset of blood lactate accumulation) [11, 15] and the mean velocity of (V) a 30 min maximum-effort swimming [12]. Recently, CV has also been shown to have a positive correlation with the endurance performance (V1500 m SF) in finswimming [16].

The required energy to swim a certain distance is supplied by aerobic and/or anaerobic energy processes, however, the relative importance of each energy process and also exercise intensity vary depending on the exercise time (and thus swimming distance) [17, 18]. Since the training regimen should be developed in accordance to time dependent metabolic profile, coaches and competitors should understand the relative importance of each swimming distance event. Oshita et al. [19] reported on the energetics of SFs, using the CV concept in the analysis. They observed that the CV was highly correlated with the V200 m, V400 m, V800 m and V1500 m SFs [19]. Therefore, aerobic performance may significantly contribute from medium-distance (i.e. 200 m) to long-distance (i.e. 1500 m) events. However, the study was not concerned with gender differences; the subjects of the study were gender-mixed (five males and five females). Numerous studies [20-27] have concluded that the aerobic or anaerobic performance in women is different from that in men. Thus, the aim of this study was to investigate the gender differences in the aerobic contribution to a SF performance in finswimming.

METHODS AND SUBJECTS

Subjects:

The subjects were sixteen monofin swimmers (eight males and eight females; 24±6 years). Means with their standard deviations of the body compositions (height and body mass) were 170.2 ± 4.8 cm and 69.7 ± 3.0 kg in male, and 160.5 ± 4.4 cm and 61.0 ± 3.2 kg in females. They were selected from the Japanese national team for the 1500 m SF. This study had been approved by Human Ethics Committee of the Graduate School of Human Development and Environment, Kobe University. Further, the participants were informed of the purpose of the present study beforehand and a statement of informed consent was obtained.

Investigation of swimming time:

In the present study, a 50 m long indoor pool was used. During a two-day period, V100 m, V200 m, V400 m, V800 m and V1500 m were recorded for each swimmer during 100, 200, 400, 800 and 1500 m SF tests performed at maximum speed. Each time, a trial was performed after a sufficient resting period (~1 h). The order of each trial test was randomized. The 400 and 800 m SF tests were used to calculate the slope of the regression line between time and distance.

Calculation of the CV:

Fig. 1 illustrates the relationship between D and T (400 and 800 m) to determine CV. In previous studies [2,3,11,

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Distance; D, swimming time; T, and velocity; V

$y = a \times T + b$

$D = V \times T = a \times T + b$

$V = a + b / T$

$※ T = \infty \div 0$

$V = a + b / 0$

$V = a$

$y = 1.73x + 23.8$
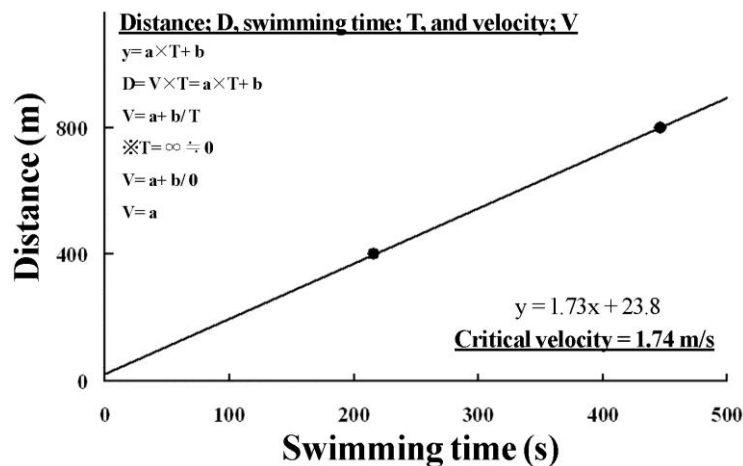
Critical velocity = 1.74 m/s

Fig. 1: An example of the slope of the linear regression line between swimming different distance (D) and its swimming time (T)

[14], CV was determined from exercise periods that were chosen to result in exhaustion within approximately 2 to 12 min. Among these ranges, the events that are officially recognized by the World Underwater Federation are the 400 and 800 m SFs. Furthermore, in a previous study, the CV was also calculated for the 400 and 800 m SFs. Thus, in the present study, the CV is also calculated for the 400 and 800 m SFs. The points in Fig. 1 were plotted on a line defined by the relationship between D and T. It follows:

D = V * T

The equation of the regression line (Y = a * X + b) can be expressed as follows:

(Y-axis is distance and X-axis is time)

D = a * T + b

D = V * T = a * T+ b

V = a + b/T

Theoretically, if the allowed time T to swim a particular distance were infinite, then exhaustion would never be an issue. In this event, b/T would approach zero and V would approach a. Therefore, the CV can be expressed as the slope of the regression line:

CV = a

Statistics:

The observed values were expressed as mean and standard deviation (SD). All analyses were performed with the JSTAT (version 11.1 for Windows) software. Comparisons of all measured variables between genders were evaluated using a student's t test (All measured variables in each group were accepted the same variance by F-test). Pearson's correlation coefficient (r) was used to examine the interrelationship between the CV and the V of each swimming distance. In these statistical analyses, the significance was accepted to be at the $p < 0.05$ levels.

RESULTS

Table 1 lists the means and standard deviations of the measured variables. All measured variates (i.e. swimming time) were faster for the males than for the females.

For females, CV was significantly correlated with V200 m, V400 m, V800 m and V1500 m (r = 0.802–0.924) (Fig. 2). This result suggests that the aerobic performance significantly contributes to SF performance for events from middle distance (i.e. 200m) to long distance (i.e. 1500 m) in female subjects.

For males, CV was significantly correlated with V800 m and V1500 m (r = 0.800–0.858) (Fig. 3). This result indicates that aerobic performance contributes significantly to the long-distance SF performances of only male subjects.

DISCUSSION

The aim of this study was to investigate the gender differences in the aerobic contribution to SF performances in finswimming, using the CV analysis method. Although CV was significantly correlated with V800 m and V1500 m for males, it was significantly correlated with V200 m, V400 m, V800 m and V1500 m for females.

The mean velocity of long-distance events (800 m and 1500 m SF) was significantly correlated with CV for males and females. Ogita [17] reports that, during the classical crawl, the accumulated oxygen uptake in male swimmers linearly increases with the exercise time.

Table 1: Means and standard deviations of the measured variables

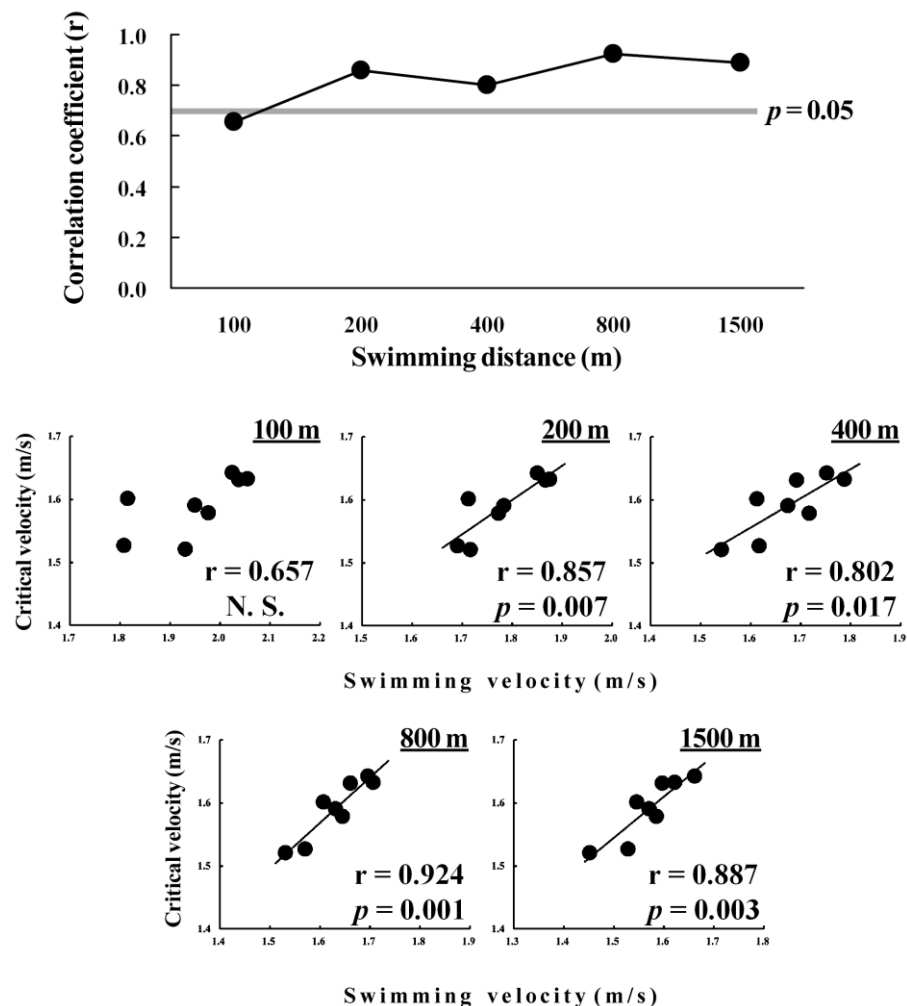|	Distance	Female	Male
Swimming time (s)	100 m	51.40 (2.41)	45.49 (1.71)
	200 m	112.3 (4.33)	100.1 (2.42)
	400 m	239.4 (10.9)	215.4 (6.67)
	800 m	491.1 (17.1)	450.4 (11.9)
	1500 m	956.6 (37.0)	879.7 (29.3)
Critical velocity (m/s)		1.591(0.04)	1.704 (0.05)

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Fig. 2: Relationship between the CV and the mean velocity of each swimming distance in females

This report suggests that the longer the duration (and thus the distance), the larger is the total amount of aerobic energy released. Furthermore, Ogita [18] suggests that the increased rate of the accumulated oxygen uptake is highly dependent on the magnitude of VO_2max, supporting the general concept that a higher maximal aerobic power can be beneficial to the performance of the endurance swimmer. Holmer's report [28] states that more than 90% of the total energy consumption comes from aerobic sources in the 1500 m swimming event or more than 600 s exercises for males. Similar energetics have been observed in females. Duffield et al. [20] reported that the relative aerobic energy system contribution for the 3000 m running event (approximately 600 exercises) was 86% (male) and 94% (female). Therefore, aerobic performances are great contributors to long distance exercises (i.e. approximately 600 exercises) both in males and in females. In the present study, the mean swimming times for the 800 m or 1500 m SF were 450-879 s for males and 491-956 s for females. Therefore, more than 800 m SFs will be important for aerobic performance. Actually, a previous study on finswimming [16] found a highly positive correlation between V1500 m and CV. Thus, both the existing literature and the results of the present study indicate that aerobic performance significantly contributes to 800 m and 1500 m SF regardless of gender.
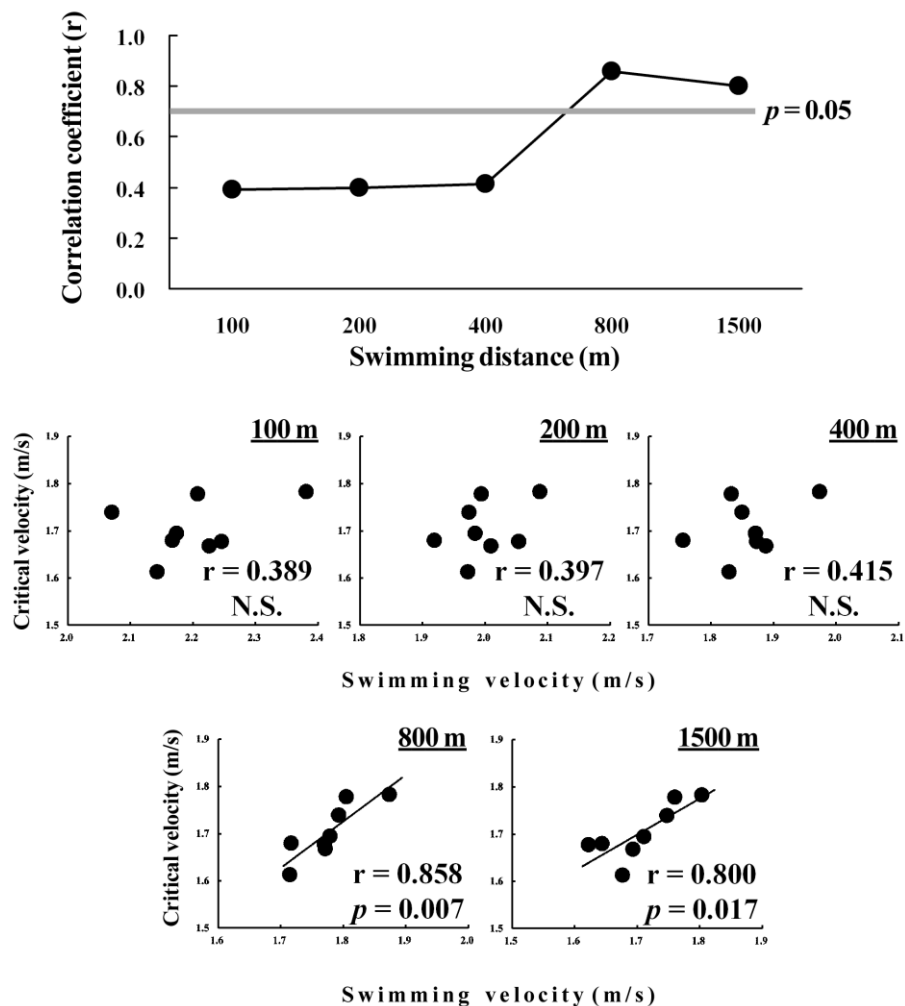
Fig. 3: Relationship between the CV and the mean velocity of each swimming distance in male

On the other hand, the mean velocity of short-distance events (i.e. 100 m) was not significantly correlated with CV in both genders. The relative importance of the anaerobic energy process during classical swimming events is reported as 78–85% for 15 s and 50% for 1 min in male swimmers [18]. In the present study, the mean swimming time for the 100 m SF was 45.4 s for males and 51.3 s for females. Therefore, the aerobic energy contribution during the 100 m SF is estimated to be less than 50%. During the 100 m running event (duration was less than 30 s), a relative aerobic/anaerobic energy system reported 21/79% and 25/75% for males and females; for the 200 m event, this was 28/72% and 33/67% for males and females, respectively [20]. Furthermore, the anaerobic energy contribution to the 400 m running event (duration was less than 60 s) averaged to 63% both for males and females [29]. These previous reports indicate that although the anaerobic energy system contribution during short duration events (less than 60 s) is lower in females than in males, this contribution is greater to short duration performances (i.e. the aerobic contribution is smaller) of both. Therefore, CV might not be significantly correlated with V100 m for both genders in the present study.

For medium-distance events (200 m and 400 m),

V200 m and V400 m were not significantly correlated with CV in males. Although the mean swimming times for these events were 100.0 s and 215.2 s, male and female, exercising for these durations is thought to be important for aerobic performance. The relative importance of the anaerobic energy system in male athletes during classical swimming events decreased from 78–85% for 15 s to 50% for 1 min to 30% for 2–3 min where the anaerobic energy supply was at a maximum [18]. Thus, the relative contribution of the aerobic energy system is 70%, or 2–3 min of classical swimming. During the 800 m running event for males (approximately 2 min), the contribution of the aerobic energy system is also 60% [20] or 61% [29]. Although previous results led us to hypothesize that CV will significantly correlate with V200 m or V400 m, the present study did not find a significant correlation. One possible reason for this discrepancy might be the difference in energy cost among finswimming, classical swimming, and running. Zamparo et al. [30] reported that the energy cost of swimming with fins is about 40% lower than that of swimming without them. Therefore, a medium-distance fin swimmer might be able to swim anaerobically for a longer duration than in classical swimming.

Although CV was not significantly correlated with V200 m and V400 m in males, the females' CV was significantly correlated. Some studies have shown that females might be able to oxidize relatively more lipids and fewer carbohydrates than males during the same relative intensity of submaximal exercise [24]. Furthermore, a lesser decline in muscle glycogen in females was also observed [24,25]. Therefore, females have a lower respiratory exchange ratio during sub-maximal endurance exercise than do males [22,24,25]. Furthermore, previous studies have observed that the maximal accumulated oxygen deficit (AOD; an index of anaerobic capacity) of females has been approximately 10-30% less with similar background [26,27]. If based on the relative to lean body mass or the estimated active muscle mass, the maximal AOD for females was also 11-18% less than that of males [26,27]. During approximately 2 min of exercise, the aerobic/anaerobic energy system contribution to the 800 m running event (approximately 2 min) was calculated as 60/40% for males and 70/30% for

females [20]. These previous studies indicate that females are able to exercise more aerobically than males can. Therefore, in the present study, the female CV might be significantly correlated with mean velocity of middle distance events, which are not significantly correlated in males.

The present study has investigated the gender-specific aerobic contribution to SF performances, using a theoretical method. However, the underlying physiological mechanisms of gender differences in the aerobic contribution to SF performances remain unclear. Therefore, future studies are required to determine the physiological indexes (i.e. analysis by expired gas, blood sampling, and so on) to clarify the mechanisms at work in the gender differences of the aerobic contributions to SF performances like those reported on in this study.

CONCLUSION

The present results suggest that the aerobic performance might contribute to SF performance for events from middle distance (i.e. 200m) to long distance (i.e. 1500m) in female participants. However, it might contribute significantly to the long-distance SF performances in male participants. Exercise program should be developed in accordance to time dependent metabolic response, because aerobic energy processes vary depending on the swimming time (and thus swimming distance). Therefore, coaches and competitors need to understand the relative importance of aerobic contribution in each swimming distance event. Our findings will provide one of the useful information to coaches and competitors.

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