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ORIGINAL PAPER

Relationships between swim performance, maximal oxygen uptake and peak power output when wearing a wetsuit

Masamitsu Tomikawa[a,*], **Takeo Nomura**[b]

[a] *KEN'S Co. Ltd., Japan*
[b] *Department of Health and Sport Sciences, Institute of Comprehensive Human Science, University of Tsukuba, Japan*

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Summary This study was intended to investigate the effect of wearing a wetsuit (WS) on physical performance capacity, which are maximal oxygen uptake ($\dot{V}O_2$max) and maximal mechanical power output (POmax), and to demonstrate whether wearing a WS affected the relationship between maximal 400 m swim performance (V400) and $\dot{V}O_2$max, and between sprint swim performance (Vsprint) and $\dot{V}O_2$max. Twelve triathletes participated in this study. $\dot{V}O_2$max was determined during the continuous progressive swimming test. The mean velocity over maximal 400 m swim was defined as V400. Active drag (AD), Vsprint and POmax were measured by a specific method called ''perturbation method''. Compared with wearing a swimsuit (SS), V400 was improved without enhancing $\dot{V}O_2$max and Vsprint was also improved without enhancing POmax and AD by wearing a WS. Significant correlations were found between V400 and $\dot{V}O_2$max and between Vsprint and POmax in the both suit conditions, but a higher correlation was found in the WS condition than in the SS condition. These results suggested that improved swim performance from wearing a WS was attributable only to improvement in technical factors, such as propulsion efficiency. In conclusion, during swimming with a WS, performance gain was not associated with physiological factors but with propulsion efficiency related to a gain in buoyancy and to drag reduction. However, when wearing a WS, V400 and Vsprint more reflected the values of $\dot{V}O_2$max and POmax, respectively.

Introduction

Wearing a wetsuit enables better swimming performance than wearing a swimsuit.[4,5,8,11,13,16,18,22] Improved swimming performance from wearing a

* Corresponding author.
E-mail address: swimtommytri@aol.com (M. Tomikawa).

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wetsuit is partly attributable to the increased stroke rate and/or stroke length.[4,13,18,22] Furthermore, triathletes, who can achieve a higher stroke rate in a wetsuit condition than in a swimsuit condition, can still further improve swimming performance.[4,23]

Performance-determining factors are categorised into those related to technique, such as stroke length and propulsion efficiency, or those related to physical performance capacity, such as maximal oxygen uptake ($\dot{V}O_2max$) and maximal mechanical power output (POmax).[24] Performance during a maximal 400 m or 400 yd swim is positively correlated with $\dot{V}O_2max$.[2,7,14] When wearing a wetsuit, no significant difference is found for $\dot{V}O_2max$ compared with wearing a swimsuit.[4,22,23] However, no study has specifically examined the effect of wearing a wetsuit on the relationship between maximal 400 m swim performance and $\dot{V}O_2max$.

Swim performance during triathlon races shows correlation with $\dot{V}O_2max$ during swimming.[1,21] Therefore, higher-endurance performance seems to be necessary to have an advantage in the swimming portion of triathlon races. In addition, sprint swim performance is important for triathletes. Triathletes start a race together and swim in the open water without lanes. They must dash ahead of others at the beginning of the swimming portion of the race so that they do not fall into ''battle swims''; a situation in which triathletes swim in a packed group while mutually disturbing one another's normal swimming strokes. Therefore, they require not only a higher-endurance performance but also better sprint swim performance. Only one study has measured performance during 50 m sprint swims with a wetsuit.[8] However, the effect of wearing a wetsuit on POmax was not considered.

This study aimed to investigate the effect of wearing a wetsuit on $\dot{V}O_2max$ and POmax, and to demonstrate whether wearing a wetsuit affected the relationship between maximal 400 m swim performance and $\dot{V}O_2max$, and between sprint swim performance and POmax.

Methods

Twelve triathletes (8 male and 4 female) participated voluntarily in this study (Table 1). Four of the participants had competed in some international triathlon races in the elite category and others had taken part in the Japan national triathlon championships and/or intercollege triathlon championships. The body surface area (SA) was calculated from their body weight and height.[15] All participants gave their informed consent. Before the study was conducted, this project was approved by the Ethical Committee of the University of Tsukuba.

Triathlon wetsuit (WS) used in this study was custom-made for each participant because some participants in a pilot investigation reported that they were inhibited in their swimming propelling motion when using a ready-made wetsuit. The WS were made of neoprene and covered the torso, the arms to the wrist and the legs to the ankles. The thickness was 5 mm for the torso and 2 mm to 3 mm for the legs and the arms. Swimsuit (SS) conditions in this study were competitive swimsuits and singlets for males and one-piece swimsuits for females. The buoyancy of a WS was evaluated as a value, which was the hydrodynamic lift (HL) with a SS subtracted from that with a WS (Table 1). The HL corresponds to the force that enables a swimmer to float in a balanced position just under the water surface.[3] The buoyancy of the WS tended to depend on SA ($r = 0.52$, $P = 0.08$).

On the first day of this study, participants performed a continuous progressive swimming test to measure $\dot{V}O_2max$ while wearing a WS or a SS in a random order. The next day, they performed two 25 m sprint swims and maximal 400 m swim in the same suit condition as the first day. These series of the swimming test and the trials in another suit condition were conducted during the following week.

The continuous progressive swimming tests were conducted to determined $\dot{V}O_2max$ and the associated velocity at which $\dot{V}O_2max$ was achieved ($V\dot{V}O_2max$) using a swimming flume (IGARASHI Industries, Tokyo, Japan). Swimming velocities during the continuous progressive swimming tests were

Table 1 Physical characteristics and performance of participants, and buoyancy of wetsuits

Participants	Age (years)	Height (cm)	Weight (kg)	Percent of body fat (%)	Body surface area (m^2)	Vbest400 (ms^{-1})	Buoyancy of wetsuits (N)
Male ($n = 8$)	20 ± 1	174 ± 4	64 ± 4	13.3 ± 1.6	1.79 ± 0.06	1.31 ± 0.12	32.3 ± 6.2
Female ($n = 4$)	21 ± 3	162 ± 4	52 ± 3	15.7 ± 2.1	1.55 ± 0.05	1.26 ± 0.15	26.2 ± 3.5
Overall ($n = 12$)	20 ± 1	170 ± 4	60 ± 4	14.0 ± 1.4	1.71 ± 0.08	1.29 ± 0.09	30.3 ± 4.5

Vbest400: the mean velocity of individual's best record for a 400 m swim.