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WHAT INFLUENCES RACE PERFORMANCE IN MALE OPEN-WATER ULTRA-ENDURANCE SWIMMERS: ANTHROPOMETRY OR TRAINING?

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ABSTRACT
Purpose. We investigated the relationship between selected variables of anthropometry and training with race performance during a 26.4 km open-water ultra-endurance swim at 23 °C in male master ultra-swimmers. Basic procedures. Fifteen non-professional male open-water ultra-endurance swimmers who were (mean ± SD) 40.0 (8.2) years of age with 83.7 (10.3) kg body mass, 1.80 (0.08) m body height and a BMI of 25.5 (2.5) kg/m² finished the race within the time limit. Body mass, percent body fat, thickness of 7 skin folds, body height, length of arm, and length of leg were measured prior to race. The number of years as active swimmer, average weekly training volume in hours and kilometres and average speed in training were recorded. The variables were then correlated to total race time. Main findings. Study participants had mean finish times of 551 (100) min and an average speed of 3.0 (0.5) km/h. Speed in swimming during training was the only variable related to total race time (r = –0.66, p = 0.0037) whereas none of the other investigated variables showed an association. Conclusions. We conclude that anthropometry was not related to race performance in these male ultra-endurance swimmers whereas speed in training showed a moderate association with total race time.

Keywords: ultra-endurance, skin-fold thickness, anthropometry, percent body fat

Introduction
Different factors are known to have an influence on endurance performance. Apart from several physiological parameters, a variety of anthropometric variables show a relationship with endurance performance. Body height [1], body fat [2, 3], upper extremity length [4], and skin-fold thickness [5] have been shown to be related to performance in competitive swimmers.

Apart from anthropometry, training variables [5–11] are also of importance. In competitive swimmers, Anderson et al. [5] could demonstrate that a combination of fitness and technique factors were important for competitive performance. According to Costill et al. [7], training intensity might be of greater importance than training volume in swimmers. In contrast, Stewart and Hopkins [8] found that better performance in swimmers over 50 m to 400 m was significantly associated with greater weekly training mileage. In a very recent study, Faude et al. [9] demonstrated that high-training volumes had no advantage in performance when compared to high-intensity training of lower volume. However, too intensive a training is counterproductive. Raglin et al. [10] found in a training study of swimmers that peak training of 8.3 km per day led to a reduction in anaerobic swimming power.

Regarding open-water swimmers, Van Heest et al. [11] reported that elite open-water swimmers were smaller and lighter than competitive pool swimmers. It is probable that swimmers with more body fat are able to endure longer time periods in cold water [12] since swimmers with less subcutaneous fat get out of the water after significantly less time during a swim in water of 9.4°C compared to 11.0°C [13]. However, in a study of male pool-swimmers in a 12 hour swim, no correlation of anthropometric variables such as body fat to race performance was found [14].

The aim of the study was to investigate the relationship of anthropometric and training variables with total race time in male open-water ultra-endurance swimmers. The variables we included as potential anthropometric predictors were body mass, percent body fat, thickness of 7 skin folds, body height and length of arm and leg, while training factors included average speed in training and average weekly training volume. These variables are considered to be related to performance in...
short-distance pool-swimmers. Since open-water swimmers, in contrast to pool-swimmers, have to swim in rather cold water [12], we expected that body fat would show an association with race performance. Our working hypothesis was that ultra-swimmers with a high percentage of body fat would be faster than swimmers with a low percentage.

Material and methods

Subjects

The organiser of the ‘Marathon Swim’ in Lake Zurich 2008 contacted all participants upon inscription to the race by a separate newsletter and informed them about the planned investigation. A total of 26 male solo swimmers started in the race. Fifteen male swimmers participated in our study. The study was approved by the Institutional Review Board of St. Gallen, Switzerland, for use of human subjects and the athletes gave their informed written consent. The anthropometric data and training variables of the athletes are presented in Tab. 1. All the swimmers were trained and experienced open-water swimmers. Three of the swimmers had already swum across the English Channel between Dover (England) and Calais (France).

The race

The 21st edition of the ‘Marathon Swim’ in Lake Zurich, Switzerland, took place on 3 August 2008. Ultra-swimmers from all over the world started in this race, the longest open-water ultra-swimming contest in Europe. The idea of this race with its first edition in 1977 was the opportunity for open-water swimmers to prepare for the Channel swim. Several swimmers preparing to cross the Channel from Dover to Calais were using this competition as practice. The swimmers started in the morning at 07:00 a.m. in Rapperswil and had to swim to Zurich; covering a total distance of 26.4 km within a time limit of 14 h (840 min). Athletes were followed by a personal support boat with a crew providing nutrition and fluids. The weather was moderate during the whole day, for details see Tab. 2.

Measurements and calculations

Before the start of the race, body mass, length of extremities, body height and skin-fold thicknesses at 7 sites were measured. Body mass was determined using a commercial scale (Beurer BF 15, Beurer GmbH, Ulm, Germany) to the nearest 0.1 kg. Body height was measured using a stadiometer to the nearest 1 cm. Percentage of

<table>
<thead>
<tr>
<th>Variable</th>
<th>r</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body mass (kg)</td>
<td>83.7</td>
<td>−0.07 n.s.</td>
</tr>
<tr>
<td>Body height (m)</td>
<td>1.80</td>
<td>−0.29 n.s.</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>25.5</td>
<td>0.40 n.s.</td>
</tr>
<tr>
<td>Length of arm (cm)</td>
<td>81.1</td>
<td>0.34 n.s.</td>
</tr>
<tr>
<td>Length of leg (cm)</td>
<td>86.2</td>
<td>−0.42 n.s.</td>
</tr>
<tr>
<td>Percent body fat (%)</td>
<td>17.9</td>
<td>0.28 n.s.</td>
</tr>
<tr>
<td>Sum of 7 skin folds (mm)</td>
<td>90.0</td>
<td>−0.30 n.s.</td>
</tr>
<tr>
<td>Number of years as active swimmer</td>
<td>17.6</td>
<td>0.33 n.s.</td>
</tr>
<tr>
<td>Average number of kilometres swum per week</td>
<td>15.8</td>
<td>0.01 n.s.</td>
</tr>
<tr>
<td>Average number of hours swum per week</td>
<td>6.7</td>
<td>0.27 n.s.</td>
</tr>
<tr>
<td>Average speed in training (km/h)</td>
<td>3.4</td>
<td>−0.66 0.0037</td>
</tr>
</tbody>
</table>

*p*-value is shown after Bonferroni correction

<table>
<thead>
<tr>
<th>Variable</th>
<th>r</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start at 07:00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air temperature (°C)</td>
<td>20.4</td>
<td></td>
</tr>
<tr>
<td>Water temperature (°C)</td>
<td>23.1</td>
<td></td>
</tr>
<tr>
<td>Relative humidity (%)</td>
<td>73</td>
<td></td>
</tr>
<tr>
<td>Wind (m/s)</td>
<td>3.1</td>
<td></td>
</tr>
<tr>
<td>Direction of the wind (°)</td>
<td>178</td>
<td></td>
</tr>
<tr>
<td>Finish at 19:00</td>
<td>28.1</td>
<td></td>
</tr>
<tr>
<td>12:00</td>
<td>24.5</td>
<td></td>
</tr>
<tr>
<td>Air temperature (°C)</td>
<td>23.3</td>
<td></td>
</tr>
<tr>
<td>Water temperature (°C)</td>
<td>55</td>
<td></td>
</tr>
<tr>
<td>Relative humidity (%)</td>
<td>42</td>
<td></td>
</tr>
<tr>
<td>Wind (m/s)</td>
<td>5.5</td>
<td></td>
</tr>
<tr>
<td>Direction of the wind (°)</td>
<td>281</td>
<td></td>
</tr>
<tr>
<td>Data were generously provided by the Sea Police Zurich</td>
<td></td>
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</tr>
</tbody>
</table>
body fat was calculated using the following anthropometric formula: Percent body fat = \(0.465 + 0.180(\Sigma 7SF) - 0.0002406(\Sigma 7SF)^2 + 0.0661(\text{age})\), where \(\Sigma 7SF = \text{sum of skin-fold thickness of chest, midaxillary, triceps, subscapular, abdomen, suprailliac and thigh mean, according to Ball et al. [15]}. This formula was evaluated using 160 men aged 18–62 years and cross-validated using DXA (dual energy X-ray absorptiometry). The mean differences between DXA percent body fat and calculated percent body fat ranged from 3.0% to 3.2%. Significant \((p < 0.01)\) and high \((r > 0.90)\) correlations existed between the anthropometric prediction equations and DXA. Skin-fold data were obtained using a skin-fold calliper (GPM-Hautfaltenmessgerät, Siber & Hegner, Zurich, Switzerland) and recorded to the nearest 0.2 mm. One trained investigator took all measurements since inter-tester variability is a major source of error in skin-fold measurements. An intra-tester reliability check was conducted prior to this testing on 27 male runners. No significant difference between the 2 trials, measuring the sum of 7 skin folds, was observed \((p > 0.05)\). The intra-class correlation was high at \(r = 0.99\). The same investigator was also compared to another trained investigator to determine objectivity. No significant difference existed between testers \((p > 0.05)\). The skin-fold measurements were taken once for the entire 7 skin folds and then repeated 2 times by the same investigator; the mean of the 3 times was then used for the analyses. The timing of taking the skin-fold measurements was standardised to ensure reliability. According to Becque et al. [16], readings were performed 4 s after applying the calliper. The length of the right arm was measured from acromion to the tip of the third finger, the length of the right leg from trochanter major to malleolus lateralis. In addition to the determination of the anthropometric variables, athletes were asked about their average weekly training volume in hours, plus the kilometres swum, in preparation for the race. Each athlete maintained a comprehensive training diary consisting of daily workouts showing distance and duration. The training diary started upon inscription to the race. The average value in volume (kilometres and hours) and intensity (km/h) were calculated. The number of years as active and competitive swimmer was also obtained. Three participants were competitive triathletes.

Statistical analysis

Results are presented as mean (SD). The coefficient of variation (CV% = 100 × SD/mean) of total race time was calculated. The Pearson correlation analysis was applied to the variables body mass, body height, BMI, length of arm, length of leg, percent body fat, sum of 7 skin folds, years as active swimmer, average number of kilometres and hours swum per week and average speed in training. The Spearman correlation analysis was applied when the data were non-normally distributed. Bonferroni corrections were applied and a statistical significance was reported with \(p < 0.0045\) (11 variables).

Results

The 26 athletes of the field finished the 26.4 km in a mean time of 551.5 (91.3) min. The fastest swimmer arrived after 377 min, setting a new course record in the master category. The slowest competitor finished after 710 min. All 15 study participants finished the race on average in 550.9 (99.5) min (CV% = 18) swimming at an average speed of 3.0 (0.5) km/h. None of the anthropometric variables investigated were associated with race performance (Tab. 1), whereas speed in swimming during training was significantly related to total race time \((r = –0.66, p = 0.0037)\) (Fig. 1).

Figure 1. Speed in training was significantly associated with total race time \((r = –0.66, p = 0.0037)\) for the 15 swimmers. Three athletes finished the race within the same minute, and 2 of them had an identical speed in training, we therefore see only 14 dots.

Discussion

In contrast to the literature regarding short distance swimmers, we found no association between performance and known anthropometric factors in swimmers.
such as fat mass [3], upper extremity length [4] and body height [4, 6] in this group of male open-water ultra-endurance swimmers.

Training intensity

In contrast to our presumption that body fat would be related to performance, we found that average speed in training was significantly associated with total race time (Fig. 1). It seems that athletes with a high training pace performed better in this ultra-endurance swim.

In the literature, neither high volume nor high intensity seem to be related to swimming performance in pool swimmers. Costill et al. [7] found in a training study of male swimmers that a high training volume did not enhance swim performance. In contrast, after a taper period, performance was improved. In another training study of competitive swimmers, a 4-week training period of both high volume and low intensity, or low volume and high intensity led to an improvement in performance [9]. Probably the incorporation of resistance training into a training programme enhances swim performance. Girold et al. [17] found in a training study of swimmers that programmes either combining swimming with dry-land strength training or with in-water resistance- and assisted-sprint exercise led to a similar gain in sprint performance, which was better than traditional training methods.

Training volume

Because of the low training volume we assumed that our subjects cannot be considered as successful athletes, but when observing the fact that they all finished the race within the time limit we cannot deduce that these athletes are not serious swimmers.

The swimmers in this sample trained, on average, a total distance of 15.8 km per week. This is very little, and suggests that these swimmers were not serious athletes, particularly for an aerobically demanding, high-endurance sport such as marathon-swimming. This point is also reflected in the average number of 6.7 hours of training per week. In comparison, the average elite competitive swimmer easily trains 3 to 4 times this distance each week. For comparison, athletes in the study of Van Heest et al. [11] swam on average just over 12 km per day during a 1 week training camp. This daily distance is almost equivalent to the average total distance swum by the participants in this study in an entire week. Swimming 26.4 km without a break at an average speed of 3 km per hour requires trained athletes. Since the average age of those swimmers is 40 years, and competitive swimmers are about 20 years younger [18, 19], we might assume that those swimmers had a long story of competitive swimming. This is reflected by the fact that these athletes had been training for 17.6 (16.1) years varying between 2 to 46 years. In addition, at least 2 athletes were former competitive swimmers at the national level in their country and at least 3 athletes were elite long-distance triathletes investing more time in cycling and running training than swimming. Presumably an older or senior competitive swimmer is able to maintain a high speed during training at low volumes for years and is therefore able to compete fast in ultra-endurance swimming.

Body height and length of extremities

We found no association between any of the anthropometric variables investigated and total race time. In contrast to our findings, in studies of pool swimmers, body mass, length of extremities and body height showed a relationship with swim performance.

Geladas et al. [4] could demonstrate in boys and girls aged 12 to 14 years that upper extremity length was, in addition to horizontal jump and grip strength, a significant predictor variable of 100 m freestyle performance in boys. In girls, body height, upper extremity and hand length were significantly related to 100 m freestyle times. Jagomagi and Jurimae [6] found in 125 female breaststroke swimmers that body height was the most important anthropometrical parameter, explaining 11.1% of the 100 m breaststroke results. The association of body weight with swim performance is probably related to gender. Sekulić et al. [20] could demonstrate that body height was related to performance in male swimmers over 50 m freestyle. Probably the length of the swim distance was the reason that we could not detect a correlation with total race time. We also found no relationship of body height to race performance, as Jagomagi and Jurimae [6] did.

Body mass and body fat

Sekulić et al. [20] showed that body mass was related to swim performance in female swimmers over 400 m freestyle and Siders et al. [2] found in female swimmers that body mass was correlated to swimming performance. Our athletes with a race distance of 26.4 km had to swim a considerably longer distance compared to
pool swimmers. We expected that high body fat would be beneficial for race performance in an open-water swim; however, fat mass showed no association with total race time. Swimmers crossing the English Channel face temperatures of about 15°C [12]. For ultra-swimmers in open-water competitions, such as the Channel, fat is a better insulator than human muscle [21]. Keatinge et al. [13] could show that swimmers with less thick subcutaneous fat made significantly shorter swims than those with thicker fat layers in water of 9.4°C to 11°C. The water temperature in Lake Zurich was constant at 23°C, so that the water temperature obviously was not a problem for those swimmers. They all finished successfully within the time limit.

In the Channel between Dover and Calais of over 32.2 km, swimmers commonly need about 12 hours, but some up to 20 hours [12] depending upon the circumstances. The finding that high fat mass seems to be advantageous for swimming performance is probably again dependent on the gender. However, also in female swimmers, a high fat mass may impair swim performance. Tuuri et al. [3] showed in female swimmers that greater fat mass is strongly related to lower levels of exercise. Siders et al. [2] could demonstrate that percent body fat was correlated to swimming performance over 100 yards in females.

Gender

Probably gender was the reason that we could not find a relationship between anthropometric variables and race performance. According to Siders et al. [2], the anthropometric variables: body height, body mass, percent body fat and fat-free mass have an effect on swimming performance in female swimmers, but not in males. Over a 100-yard swim of each swimmer’s major competitive stroke, these 4 parameters showed an effect on performance. Interestingly, these 4 variables only showed an effect on performance in the female competitive swimmers, and not in the men. In contrast to these results, Geladas et al. [4] found that upper extremity length, hand length, and body height were significantly related to 100 m freestyle time, but the degree of association was markedly lower in girls than in boys.

Conclusions

This investigation suggests that anthropometric variables such as body fat, body height and length of extremities show no relationship to race time in male ultra-endurance swimmers in an open-water ultra-swimming contest as has been shown in pool-swimmers over shorter distances. In this group of ultra-swimmers, speed in training appears to have a modest association with race performance in a 26.4 km open-water ultra-swim. Further investigation is warranted in a larger sample of athletes to clarify why speed in training is important for performance in open-water ultra-endurance swimmers and not body fat. Especially the intensity of training should be determined using parameters such as heart rate or blood lactate. Furthermore, differences between genders should be investigated.

Acknowledgements

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References


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