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A Comparison of Anthropometry between Ironman Triathletes and Ultra-swimmers

by
Beat Knechtle[1,2], Barbara Baumann[1], Patrizia Knechtle[1], Andrea Wirth[1], Thomas Rosemann[2]

We intended to compare the anthropometry of male and female Ironman triathletes with the anthropometry of male and female ultra-swimmers. Body mass, body mass index and body fat were lower in both male and female triathletes compared to swimmers. Body height and length of limbs were no different between the two groups. In the multi-variate analysis, in male triathletes, body mass (p=0.015) and percent body fat (p=0.0003) were related to race time; percent body fat was also related to the swim split (p=0.0036). In male swimmers, length of the arm was related to race time (p=0.0089). In female triathletes and swimmers, none of the investigated anthropometric variables showed an association with race time. We concluded that Ironman triathletes and ultra-swimmers were different regarding anthropometry and that different anthropometric variables were related to race time. We assume that other factors, such as training and equipment, as opposed to anthropometry, may better predict race time in male and female Ironman triathletes.
Key words: *body fat, body mass, body height, skin-fold thickness*

Introduction

The sports discipline of triathlon comprises swimming, cycling and running. Races are mainly performed over the short (Olympic) distance of 1.5 km swimming, 40 km cycling and 10 km running (Sultana et al., 2008) and the Ironman distance of 3.8 km swimming, 180 km cycling and 42.2 km running (Lepers, 2008; Lepers et al., 2009; Neubauer et al., 2008). The Ironman distance is the most popular triathlon distance. Since the first event in 1978, every year thousands of triathletes compete in Ironman races in effort to qualify for the Ironman Hawaii, where more than 1,700 triathletes compete in the World Championship (Lepers, 2008).

Competing and finishing an Ironman triathlon needs training and racing in three different disciplines, where, apart from physiological variables, different variables of anthropometry might be associated with performance. There is little data about the association between anthropometry and race performance for Ironman triathletes. Short-distance triathletes described by Sleivert and Rowlands (1996) showed that elite triathletes were generally tall, of average to light weight and had low levels of body fat. Landers et al. (2000) showed that low levels of body fat were important for overall race time, and split times, and that longer segmental lengths contributed to a successful swimming outcome. Leake and Carter (1991) concluded that short distance triathletes were closer, with respect to

[1] - *Gesundheitszentrum St. Gallen, St. Gallen, Switzerland*
[2] - *Institute of General Practice and Health Services Research, University of Zurich, Zurich, Switzerland*

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both body composition and somatotype, to swimmers than to runners. For Ironman triathletes, a comparison of body height, weight, and percent body fat of Ironman triathletes, with the data in literature of elite athletes from the sports of swimming, cycling and running, showed that the physique of triathletes was most similar to that of cyclists rather than swimmers or runners (O'Toole et al., 1987).

To date, no study has compared the anthropometric data of Ironman triathletes with long-distance swimmers. Since most professional Ironman triathletes complete their total race distance within 10 to 11 hours (Neubauer et al., 2008), we compared the anthropometric and training variables of Ironman triathletes to ultra-distance swimmers participating in the 'Marathon Swim' in Lake Zurich, the longest open-water ultra-swim in Europe. In this competition the athletes have to cover the distance of 26.7 km within 12 hours, comparable to an average race time for Ironman triathletes. Respecting existing literature from O'Toole et al. (1987), we hypothesised that the anthropometry of Ironman triathletes would be different compared to ultra-swimmers, and that anthropometric variables in Ironman triathletes would be differently related to race time compared to ultra-swimmers.

Material & methods

The athletes in both races were informed about the planned investigation by newsletter sent by the organisers. Interested athletes volunteering for the study were informed of the procedures and gave their informed consent prior to the investigation. The investigation was approved by the Ethical Committee of St. Gallen, Switzerland.

'Marathon Swim' Zurich

Open water ultra endurance swimmers represent a very small group (Keatinge et al., 2001; Van Heest et al., 2004). In order to increase the sample size, we collected data in two subsequent years at the 'Marathon Swim' in Lake Zurich in Switzerland. 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, when first held in 1977, was the opportunity for open water swimmers to prepare for the Channel swim between Dover (England) and Calais (France). Several swimmers preparing to cross the Channel were using this competition as practice. The 21st annual event of the 'Marathon Swim' in Lake Zurich, Switzerland, took place on 3 August 2008; the 22nd on 26 July 2009. The swimmers started in the morning at 07:00 a.m. in Rapperswil and swam to Zurich; covering a total distance of 26.4 km within a time limit of 14 h (840 min). The athletes were followed by a personal support boat with a crew providing nutrition and fluids. The weather in both years was essentially the same. In 2008, the temperature of the Lake was 22 °C; in 2009 it was at 21 °C. It was dry and sunny throughout the day, with both years having daily highs of 27 °C.

Ironman Switzerland

On 12 July 2009 'IRONMAN SWITZERLAND' took place in the heart of the City of Zurich, Switzerland. A total of 2,534 male and 359 female Ironman triathletes from 49 countries were inscribed on the start list and started in the morning at 07:00 a.m. At the start, the air temperature was 14° Celsius and the water in Lake Zurich was 20° Celsius. Due to the low water temperature, wet suits were allowed. At the start, the sky was clear and became cloudy slowly during the afternoon and evening. The highest water temperature, 22° Celsius, was reached in the afternoon. The athletes had to swim two laps in the Lake to cover the 3.8 km distance, and then cycled two laps of 90 km each, followed by running four laps of 10.5 km each. In the cycling discipline, the highest point to climb from Zurich (400 metres above sea level) was the 'Forch' (700 metres above sea level), while the running course was completely flat in the City of Zurich. Nutrition was provided for the cycling and running courses by the organisers. They offered bananas, energy bars, energy gels and carbohydrate drinks, as well as caffeinated drinks and water on the cycling course. On the running course, in addition to the aforementioned nutrition, different fresh fruits, dried fruits, nuts, chips, salt bars and soup were provided.

Subjects

Table 1a represents the anthropometric data for both the male Ironman athletes and the ultra-swimmers, **Table 1b** for both the female Ironman athletes and ultra-swimmers. In the Ironman, a total of 98 non-professional male Ironman triathletes volunteered for the investigation; 83 participants completed the race within the time limit of 16 hours. Among the female triathletes, a total of 37 non-

Table 1a
Comparison of age and anthropometry between male Ironman triathletes and male ultra-swimmers. Results are presented as mean (SD)

	Male Ironman triathletes (n=83)	Male ultra-swimmers (n=28)
Age (years)	41.5 (8.9)	38.1 (9.0)
Body mass (kg)	77.3 (8.9) **	85.3 (10.6)
Body height (m)	1.80 (0.07)	1.82 (0.08)
Body mass index (kg/m²)	23.7 (2.1) **	25.7 (2.8)
Percent body fat (%)	15.7 (4.6) **	20.1 (6.1)
Length of arm (cm)	81.5 (4.1)	82.8 (4.2)
Length of leg (cm)	86.4 (5.0)	87.9 (5.3)

Table 1b
Comparison of age and anthropometry between female Ironman triathletes and female ultra-swimmers. Results are presented as mean (SD)

	Female Ironman triathletes (n=31)	Female ultra-swimmers (n=17)
Age (years)	36.8 (6.2)	39.4 (10.7)
Body mass (kg)	60.1 (6.1) **	71.0 (6.4)
Body height (m)	1.66 (0.06)	1.68 (0.05)
Body mass index (kg/m²)	21.6 (1.2) **	25.1 (2.1)
Percent body fat (%)	24.9 (6.4) **	31.4 (3.7)
Length of arm (cm)	74.0 (3.7)	74.6 (3.3)
Length of leg (cm)	82.1 (4.4)	82.4 (3.3)

professional female Ironman triathletes volunteered to participate in the investigation. Thirty-one athletes in our study group finished the race successfully within the time limit. In the 'Marathon Swim' in 2008, of the total 26 male and 9 female solo swimmers that started in the race, 15 male and 7 females volunteered to participate in our study. In 2009, of the 18 males and 13 females which started, 14 male and 10 female swimmers participated in our investigation. In total, 29 male and 17 female swimmers entered as study participants.

Measurements and Calculations

The day before the start of the race, body mass, body height, length of arm and leg, circumferences of limbs and thicknesses of skin folds were measured. With this data we calculated body mass index and percent body fat. 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. Skin-fold data was obtained using a skin fold calliper (GPM-Hautfaltenmessgerät, Siber & Hegner, Zurich, Switzerland) and recorded to the nearest 0.2 mm. The skin-fold measurements were taken once for the entire eight skin folds (pectoral, triceps, mid-axilla, subscapular, abdominal, suprailiac, front thigh and medial calf) and were repeated twice more by the same investigator; the mean of the three measurements was then used for the analyses. According to Becque et al. (1986), the readings of skin-fold thicknesses 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*. Percentage of body fat in men was calculated using the following anthropometric formula: Percent body fat = $0.465 + 0.180(\Sigma 7SF) - 0.0002406(\Sigma 7SF)^2 + 0.0661(age)$, where Σ7SF = sum of skin-fold thickness of pectoral, triceps, mid-axilla, subscapular, abdominal, suprailiac and front thigh mean, according to Ball et al. (2004a). For females, percent body fat was calculated using the following formula: Percent body fat = $-6.40665 + 0.41946 (\Sigma 3SF) - 0.00126 (\Sigma 3SF)^2 + 0.12515 (Hip) + 0.06473 (age)$, using the formula of Ball et al. (2004b). Σ3SF was taken as the sum of skin-fold thickness of the triceps, suprailiac and front thigh skin-fold thicknesses. The hip circumference (Hip) was measured in cm at the widest point over the buttocks.

Statistical Analyses

The anthropometric data of both triathletes and swimmers were compared using the Kruskal-Wallis equality-of-populations rank test. The association of the anthropometric variables of body height, body mass, length of leg, length of arm and percent body fat, with total race time for both triathletes and swimmers, and with the swim split time for the triathletes, was investigated using multiple linear regression analysis. A power calculation was performed according to Gatsonis & Sampson (1989). To achieve a power of 80% (two-sided Type I error of 5%) to detect a minimal association between race time and anthropometric variables of 20% (i.e., coefficient of determination $R^2 = 0.2$), a sample of 40 participants was required.

Results

For the ultra-swimmers, the male and female athletes in both the 2008 and 2009 race were no different regarding anthropometry and final race time. One male athlete in the 2009 race had to give up due to seasickness. The 28 male swimmers

Table 2a
Multiple linear regression analysis with total race time as the dependent variable for male Ironman triathletes (n=83). ß = regression coefficient; SE = standard error of the regression coefficient; Coefficient of determination (r^2) of the model was 32%)

	ß	SE	p-value
Body height	- 279.3	293.9	0.34
Body mass	2.78	1.12	0.015
Length of leg	- 1.2	- 0.44	0.66
Length of arm	3.43	3.13	0.27
Percent body fat	6.37	1.69	0.0003

Table 2b
Multiple linear regression analysis with split time in the swim as the dependent variable for male Ironman triathletes (n=83). ß = regression coefficient; SE = standard error of the regression coefficient; Coefficient of determination (r^2) of the model was 18%.

	ß	SE	p-value
Body height	15.24	55.10	0.78
Body mass	0.17	0.21	0.40
Length of leg	- 0.56	0.54	0.30
Length of arm	0.08	0.58	0.88
Percent body fat	0.95	0.31	0.0036

finished within 534 (93) min, swimming at an average speed of 3.05 (0.55) km/h. The 17 females swam no slower compared to the males ($p > 0.05$), within 596 (120) min and swimming at 2.74 (0.45) km/h. The race times of the males, expressed as a percentage of the course record of 351 min set by Maarouf Mohamed (Egypt) in 1993, were 152 (26) %; in females, expressed as a percentage of the record of 359 for females set in 2001 by Nadja Krüger (Switzerland), they were 166 (33) % of the course record. Also when race time was expressed as a percentage of the course record, females were no slower compared to males. The male Ironman triathletes completed the 3.8 km swim, 180 km bike and 42.195 km run within 689 (79) min.. Expressed as a percentage of the course record (8:12 h:min by Olivier Bernhard, Switzerland) the athletes finished after 139 (15) %. The 31 female finishers completed the distance within 745 (81) min, significantly slower compared to the male Ironman triathletes. Expressed as a percentage of the course record (9:10 h:min by Karin Thürig, Switzerland), the athletes finished after 135 (14) %. Body mass, body mass index and body fat was lower in both male (**Table 1a**) and female (**Table 1b**) Ironman triathletes, compared to ultra-swimmers. Body height and length of limbs were no different between the two groups of athletes. In male Ironman triathletes, both body mass and percent body fat were related to total race time (**Table 2a**); percent body fat was also related to the swim split (**Table 2b**). In male ultra-swimmers, length of the arm was related to race time (**Table 3**). In female Ironman triathletes, none of the investigated anthropometric variables showed an association with total race time (**Table 4a**), or with the swim split time (**Table 4a**). Also in female ultra-swimmers, none of the anthropometric variables were related to race time (**Table 5**).

Discussion

The aim of this study was to compare the anthropometry of Ironman triathletes and ultra-endurance swimmers. Respecting the existing literature from O'Toole et al. (1987), we hypothesised

Table 3
Multiple linear regression analysis with race time as the dependent variable for male ultra-swimmers (n=28). ß = regression coefficient; SE = standard error of the regression coefficient; Coefficient of determination (r^2) of the model was 50%.

	ß	SE	p-value
Body height	- 736.4	438.5	0.10
Body mass	2.62	2.44	0.29
Length of leg	15.0	7.48	0.056
Length of arm	- 22.1	7.70	0.0089
Percent body fat	5.78	4.01	0.16

Table 4a
Multiple linear regression analysis with race time as the dependent variable for female Ironman triathletes (n=31). ß = regression coefficient; SE = standard error of the regression coefficient; Coefficient of determination (r^2) of the model was 7%.

	ß	SE	p-value
Body height	- 163	841.1	0.84
Body mass	3.74	9.45	0.69
Length of leg	- 6.9	7.87	0.39
Length of arm	4.79	7.55	0.53
Percent body fat	- 0.29	5.01	0.95

Table 4b

Multiple linear regression analysis with split time in the swim as the dependent variable for female Ironman triathletes (n=31). ß = regression coefficient; SE = standard error of the regression coefficient; Coefficient of determination (r^2) of the model was 11%.

	ß	SE	p-value
Body height	- 25.6	113.5	0.82
Body mass	- 0.23	1.27	0.85
Length of leg	- 0.67	1.06	0.53
Length of arm	1.30	1.01	0.21
Percent body fat	0.21	0.67	0.74

Table 5

Multiple linear regression analysis with race time as the dependent variable for female ultra-swimmers (n=17). ß = regression coefficient; SE = standard error of the regression coefficient; Coefficient of determination (r^2) of the model was 43%.

	ß	SE	p-value
Body height	- 1185	885	0.20
Body mass	3.53	6.70	0.60
Length of leg	16.2	12.4	0.21
Length of arm	- 10.5	11.9	0.39
Percent body fat	15.6	10.0	0.14

that the anthropometry of the Ironman triathletes would be different compared to the ultra-swimmers, and that the anthropometric variables of Ironman triathletes would be differently related to race time compared to ultra-swimmers.

Both male and female Ironman triathletes had a lower body mass, lower body mass index and lower body fat compared to both male and female ultra-swimmers. When we investigated the association of anthropometry with performance, body mass and percent body fat were related to race time in male Ironman triathletes, percent body fat was also related to the swim split time for the Ironman triathletes. In male ultra-swimmers, length of arm was related to race time. For female athletes, however, none of the investigated variables of anthropometry was related to race time.

It is difficult to discuss and compare the results of the anthropometry of Ironman triathletes with the literature, since we found no data about the association of anthropometry with performance in Ironman triathletes. Regarding the coefficients of determination in Table 1 (32%) and Table 2 (18%), we must assume that variables other than anthropometry might be of higher importance in predicting race time in Ironman triathletes. Gulbin and Gaffney (1999) illustrated that the previous best performances in an Olympic distance triathlon, coupled to weekly cycling distances and longest training ride, could partially predict (r^2 = 0.57) overall Ironman race performance.

An interesting finding is that percent body fat was related to the swim split in male Ironman triathletes, but not in male ultra-swimmers. The water temperature in Lake Zurich during summer is generally above 20° Celsius. 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, body fat percentage showed no association with total race time. Swimmers crossing the English Channel face temperatures of about 15 °C (Pugh and Edholm, 1955). For ultra-swimmers in open-water competitions, such as the Channel, fat is a better insulator compared to human muscle (Pugh and Edholm, 1955). Keatinge et al. (2001) showed 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. In the Channel between Dover and Calais, over a 32.2 km distance, swimmers commonly need about 12 hours, but some up to 20 hours, depending upon the circumstances (Pugh and Edholm, 1955). The finding that high fat mass seems to be advantageous for swimming performance is probably dependent on the gender. However, in female swimmers, also, a high fat mass may impair swim performance. Tuuri et al. (2002) showed in female swimmers that greater fat mass was strongly related to lower levels of exercise. Siders et al. (1993) demonstrated that percent body fat was correlated to swimming performance over 100 yards in females.

The water temperature in Lake Zurich was consistently above 20 °C, so that the water temperature obviously was not a problem for these ultra-swimmers. They finished successfully within the time limit with the exception of the male swimmer with seasickness. Water temperature must be around 10 °C (Keatinge et al., 2001) or less (Knechtle et al., 2009) for body fat to be of importance. It is assumed that swimmers with more body fat can perform longer in cold water (Keatinge et al., 2001) and an increase in fat mass is recommended (Acevedo et al., 1997) before a swim in cold water. In the study of Keatinge et al. (2001), the subject with the thinnest skin-fold thickness (mean skin-fold thickness of four skin-folds) of 8.56 mm swam for 23 minutes in 11 °Celsius.

In the multivariate analysis, length of arm was related to race time in male ultra-swimmers. This is in line with findings in studies of pool swimmers, where body mass, length of extremities and body height showed a relationship with swim performance. Geladas et al. (2005) demonstrated 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.

Limitations of the present study and implications for future research

The study is limited due to the smaller sample size of female triathletes and swimmers compared to male athletes. Regarding our power analysis, the sample size was large enough for male athletes, but rather limited regarding female participants. However, the percentage of female starters in ultra-endurance events is very small. When we look at the coefficients of determination, r^2 was 7% of total race time for the female triathletes, and 11% for the swim split. These very low coefficients might be a hint that other factors such as pre-race experience, training or equipment might be of importance in predicting race time for female Ironman triathletes. For female ultra-swimmers, we also found no association between anthropometry and race time, but coefficient of determination was 43%. This might also indicate that a technical discipline such as triathlon, where cycling is a large part of the competition, has other predictor variables than swimming. Other factors such as training and equipment may also have an effect on race time in Ironman triathletes. In future studies with Ironman triathletes, the anthropometry of triathletes should be compared with the anthropometry of cyclists. Furthermore, the aspect of training should be taken into consideration.

To conclude, Ironman triathletes and ultra-swimmers were different in anthropometry, and different anthropometric variables were related to race time. We assume that Ironman triathletes are not anthropometrically similar to ultra-swimmers.. Regarding recent findings with Triple Iron triathletes, where cycling (Knechtle et al., 2007) and running performance (Knechtle et al., 2007; Knechtle and Kohler, 2009) were related to total race time, Ironman triathletes may be closer to cyclists or runners regarding the association between anthropometry and race time. In future studies, that anthropometry of cyclists should be compared with the anthropometry of Ironman triathletes.

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Corresponding author

PD Dr. med. Beat Knechtle
Facharzt FMH für Allgemeinmedizin
Gesundheitszentrum St. Gallen
Vadianstrasse 26
9001 St. Gallen, Switzerland
Phone:+41 (0) 71 226 82 82
Fax: +41 (0) 71 226 82 72
e-mail: beat.knechtle@hispeed.ch