

The Relationship between Anthropometry and Split Performance in Recreational Male Ironman Triathletes

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Abstract

Purpose: The aim of this study was to investigate the relation between anthropometric variables and total race time including split times in 184 recreational male Ironman triathletes.

Methods: Body mass, body height, body mass index, lengths and circumferences of limbs, thicknesses of skin-folds, sum of skin-fold thicknesses, and percent body fat were related to total race time including split times using correlation analysis and effect size.

Results: A large effect size ($r > 0.37$) was found for the association between body mass index and time in the run split and between both the sum of skin-folds and percent body fat with total race time. A medium effect size ($r = 0.24-0.36$) was observed in the association between body mass and both the split time in running and total race time, between body mass index and total race time, between both the circumferences of upper arm and thigh with split time in the run and between both the sum of skin-folds and percent body fat with split times in swimming, cycling and running.

Conclusions: The results of this study showed that lower body mass, lower body mass index and lower body fat were associated with both a faster Ironman race and a faster run split; lower circumferences of upper arm and thigh were also related with a faster run split.

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INTRODUCTION

The sports discipline triathlon includes swimming, cycling and running. It can be performed over the short (Olympic) distance of 1.5 km swimming, 40 km cycling and 10 km running^[1], the Ironman distance of 3.8 km swimming, 180 km cycling and 42.2 km running^[2-4] and longer distances such as the Triple Iron ultra-triathlon distance over 11.4 km swimming, 540 km cycling and 126.6 km running^[5-7]. The Ironman

distance is the most popular long-distance triathlon. Since the first edition in 1978, every year, thousands of triathletes compete in Ironman races in order to be qualified for the Ironman Hawaii. Every year, more than 1,700 triathletes start in the World Championship in Hawaii^[2,8]. Competing and finishing an Ironman triathlon needs training and racing in three different disciplines, where different anthropometric variables might be associated with performance besides physiological variables. The relationship between

anthropometry and race performance in triathletes has been investigated in short distance triathletes. Landers *et al.*^[9] described that segmental lengths and low levels of body fat were associated with race time. According to Sleivert and Rowlands^[10], male elite triathletes were tall, had low body mass and low body fat. However, apart from anthropometry, Leake and Carter^[11] concluded that training parameters such as training distance, training time and training experience in years were more important compared with anthropometric measurements regarding race outcome.

Although the Ironman distance is the most famous long-distance triathlon, there is little data about the association of both anthropometry^[12] and training volume^[13] with race performance in male Ironman triathletes. In recent studies, percent body fat was significantly and positively correlated with race time for male Ironman triathletes^[14-16]. When body height, body mass and percent body fat of Ironman triathletes were compared with results of elite athletes from swimming, cycling and running, the physique of Ironman triathletes was most similar to that of cyclists^[12]. Recent findings showed that the anthropometry of Ironman triathletes was not similar to ultra-swimmers^[17]. In a study investigating male Triple Iron ultra-triathletes^[18], the sum of eight skin-fold thicknesses was related to both total race time and split time in the run and it was concluded that male ultra-endurance triathletes were close to male runners regarding the association between anthropometric characteristics and race time including split times. However, a recent study comparing triple Iron ultra-triathletes and ultra-runners regarding the association of anthropometric and training characteristics with race performance showed that ultra-triathletes were not similar to ultra-runners in their anthropometric measures and training variables^[19]. Additionally, training volume^[13] especially in cycling^[20] seems to influence race performance in the Ironman distance. Based upon these findings, Ironman triathletes would be similar to cyclists regarding the association of anthropometry with race performance. This hypothesis might be supported by the finding that training distances appear to be more important compared with training paces in race preparation^[13] for Ironman triathletes, where weekly cycling distances were

associated with race time^[20].

The aim of the present investigation was to investigate male Ironman triathletes regarding potential associations between anthropometry and race time including split times. Since the physique of male Ironman triathletes was similar to that of male cyclists^[5], it was hypothesized that anthropometric characteristics in male Ironman triathletes would be related to split time in the cycling section rather than to the split time in the swim or run sections.

METHODS AND SUBJECTS

Subjects:

The organiser of the IRONMAN SWITZERLAND in 2009 and 2010 contacted all starters via a newsletter three months before the race and asked them to participate in our investigation. A total of 202 non-professional male Ironman triathletes volunteered to participate in the investigation. The study was approved by the Institutional Review Board for use of Human Subjects of the Canton of St. Gallen, Switzerland. The athletes were informed of the procedures of the investigation and gave their informed written consents. A total of 184 male Ironman triathletes with 40.9 (8.4) (mean (SD)) years of age, 1.80 (0.06) m of body height and 76.3 (8.3) kg of body mass out of the study group finished the race successfully within the time limit of 16 hours. Their anthropometry is shown in Table 1 and their training parameters are presented in Table 2.

Race:

In IRONMAN SWITZERLAND, the athletes had to swim two laps in the lake to cover the 3.8 km distance, and then, had to cycle two laps of 90 km each which was followed by running four laps of 10.5 km each. In the cycling part, the highest point to climb from Zurich (400 metres above the sea level) was the 'Forch' (700 metres above the sea level) while the running course was completely flat in the City of Zurich. The nutrition was provided for the cycling and running courses by the organiser. They offered bananas, energy bars,

Table 1: Anthropometric variables of the finishers (n=184). Values are given as mean (SD). The results are correlated with total race time and the split times. *P*-value is inserted in case of a significant association.

Variable	Results	Total race time	Time in the swimming split	Time in the cycling split	Time in the running split
Body mass (kg)	76.3 (8.3)	0.25, <i>P</i> =0.005 #	0.09	0.14	0.36, <i>P</i> <0.0001 #
Body height (m)	1.80 (0.06)	0.02	- 0.01	- 0.05	0.07
Body mass index (kg/m ²)	23.5 (2.0)	0.32, <i>P</i> <0.0001 #	0.12	0.22, <i>P</i> =0.002 †	0.40, <i>P</i> <0.0001 §
Length of leg (cm)	86.2 (4.8)	- 0.04	- 0.09	- 0.05	0.00
Length of arm (cm)	80.7 (4.2)	0.04	0.00	0.00	0.08
Circumference of upper arm (cm)	30.1 (2.9)	0.21, <i>P</i> =0.003 †	0.06	0.15, <i>P</i> =0.042 †	0.28, <i>P</i> =0.0001 #
Circumference of thigh (cm)	54.4 (3.4)	0.19, <i>P</i> =0.009 †	0.10	0.10	0.27, <i>P</i> =0.0002 #
Circumference of calf (cm)	37.1 (3.3)	0.17, <i>P</i> =0.022 †	0.05	0.12	0.22, <i>P</i> =0.0027 †
Sum of eight skin-folds (mm)	82.0 (34.0)	0.37, <i>P</i> <0.0001 §	0.30, <i>P</i> <0.0001 #	0.34, <i>P</i> <0.0001 #	0.33, <i>P</i> <0.0001 #
Percent body fat (%)	15.1 (4.5)	0.41, <i>P</i> <0.0001 §	0.35, <i>P</i> <0.0001 #	0.36, <i>P</i> <0.0001 #	0.35, <i>P</i> <0.0001 #

† small effect size (*r* = 0.1 – 0.23)/ # medium effect size (*r* = 0.24 - 0.36)/ § large effect size (*r* = 0.37 or larger)

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. Weather conditions in both years were comparable.

Measurements and Calculations:

The day before the start of the race body mass, body height, lengths of arm and leg, circumferences of limbs, and thicknesses of skin-folds were measured. Lengths and circumferences of limbs as well as skin-fold thicknesses were measured on the right side of the

Table 2: Training variables of the finishers (n=184). Values are given as mean (SD). The results are correlated with total race time and the split times. *P*-value is inserted in case of a significant association.

Variable	Results	Total race time	Time in the swim split	Time in the cycling split	Time in the run split
Weekly training volume (h)	13.9 (5.0)	- 0.09	- 0.09	- 0.13	0.00
Weekly swimming hours (h)	2.5 (1.2)	- 0.15, <i>P</i> =0.0386 †	- 0.18, <i>P</i> =0.013 †	-	-
Weekly cycling hours (h)	7.1 (2.5)	- 0.11	-	- 0.13	-
Weekly running hours (h)	4.3 (3.0)	0.00	-	-	0.03
Weekly swimming kilometres (km)	6.2 (3.1)	- 0.22, <i>P</i> =0.0030 †	- 0.31, <i>P</i> <0.0001#	-	-
Weekly cycling kilometres (km)	194.0 (76.6)	- 0.23, <i>P</i> =0.0018 †	-	- 0.25, <i>P</i> =0.0008#	-
Weekly running kilometres (km)	45.0 (15.9)	0.21, <i>P</i> =0.0046 †	-	-	- 0.20, <i>P</i> =0.006 †
Speed in swimming training (km/h)	2.9 (0.6)	- 0.31, <i>P</i> <0.0001#	- 0.26, <i>P</i> =0.0003#	-	-
Speed in cycling training (km/h)	28.4 (3.2)	- 0.29, <i>P</i> <0.0001#	-	- 0.33, <i>P</i> <0.0001#	-
Speed in running training (km/h)	11.5 (1.4)	- 0.31, <i>P</i> <0.0001#	-	-	- 0.38, <i>P</i> <0.0001§

† = small effect size (*r* = 0.1 – 0.23)/ # = medium effect size (*r* = 0.24 - 0.36)/ § = large effect size (*r* = 0.37 or larger)

body. As inter-tester variability is a major source of error in anthropometric measurements, one trained investigator took all the measurements. With this data, we calculated body mass index, the sum of skin-folds, and percent body fat using an anthropometric method. Body mass was measured using a commercial scale (Beurer BF 15, Beurer, Ulm, Germany) to the nearest 0.1 kg. Body height was measured using a stadiometer to the nearest 1.0 cm. The circumferences and lengths of limbs were measured using a non-elastic tape measure (cm) (KaWe CE, Kirchner und Wilhelm, Germany). The length of the arm was measured from *acromion* to the tip of the third finger to the nearest 0.1 cm; the length of the leg from *trochanter major* to the *malleolus lateralis* to the nearest 0.1 cm. The circumference of the upper arm was measured in the middle of the upper arm (between *acromion* and *olecranon*) to the nearest 0.1 cm; the circumference of the thigh was taken at the level where the skin-fold thickness of thigh was measured (20 cm above the upper margin of the patella) and the circumference of the calf was measured at the maximum circumference of the calf. All skin-fold data were 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 all eight skin-folds, the procedure was repeated twice more and the mean of the three measurements was then used for the analysis. An intratester reliability check was conducted on 27 male runners prior to testing. Intra-class correlation (ICC) within the two judges was excellent for both men and women for all anatomical measurement sites (ICC>0.9)^[21]. The timing of taking the skin-fold measurements was standardized to ensure reliability. According to Becque *et al.*^[22] readings were performed 4 s after applying the calliper. Percent body fat was calculated using the following anthropometric formula for men:

$$\text{Percent body fat} = 0.465 + 0.180(\Sigma 7\text{SF}) - 0.0002406(\Sigma 7\text{SF})^2 + 0.0661(\text{age})$$

where $\Sigma 7\text{SF}$ = sum of skin-fold thickness of chest, midaxillary, triceps, subscapular, abdomen, suprailiac and thigh mean, according to Ball *et al.*^[23].

Upon inscription to the study, the subjects were asked to record their training units showing duration

(min) and distance (km) for all three disciplines. The investigator provided an electronic EXCEL file, where the subjects could insert each training unit with distance, duration and speed, expressed in km/h. The investigator calculated then the mean weekly hours, the mean weekly kilometres and the mean speed per discipline during the race preparation.

Statistical Analysis:

The Shapiro-Wilk test was used to check normality distribution. Normally distributed data are presented as mean and (SD). The directly measured anthropometric characteristics including body mass, body height, lengths and circumferences of limbs and the calculated anthropometric characteristics including body mass index, the sum of eight skin-folds and percent body fat were related to total race time including split times using Pearson correlation analysis. Total race time was also expressed in percent of the course record. Statistical significance was set at $p < 0.05$. Effect size of Pearson's correlation is given as † = small effect size for $r = 0.1 - 0.23$, # = medium effect size for $r = 0.24 - 0.36$ and § = large effect size for $r = 0.37$ or larger following Cohen^[24,25]. Statistical analysis was performed using 'Analyse-it Software' (City West Business Park, 3 The Boulevard, Leeds, LS12 6LX, United Kingdom).

RESULTS

Performance of the subjects:

Of the 202 participants, 184 (91%) subjects completed the race within the time limit. The subjects finished within 11:26 h:min on average. Expressed in percent of the course record, the athletes finished after 140 (16) % of the fastest time on this course of 8:12 h:min, held since 2000 by Olivier Bernhard (Switzerland). The fastest subject finished after 9:11 h:min, 51 min behind the winner. The association between time spent on swimming ($r=0.68$), cycling ($r=0.92$) and running ($r=0.89$) with total race time showed all a large effect size.

Association of anthropometric characteristics with Ironman race time:

The relationship of anthropometric characteristics with total race time including the split times is summarized in Table 1. A small effect size was found between the association of limb circumferences and total race time, between the association of body mass index and time in the cycling split, between the association of circumference of upper arm and time in the cycling split and between the association of the circumferences of the calf and time in both the run split and total race time. A medium effect size was found for the relationship of body mass with total race time and time in the run split, the relationship of body mass index with total race time, the association of both percent body fat and the sum of skin-folds with times in the swimming, cycling and running split, and the association of circumference of upper arm and thigh with time in the running split. A large effect size was found for the relationship between both percent body fat and the sum of skin-folds and total race time, and between the association of body mass index with time in the running split.

Association of training characteristics with Ironman race time:

The relationship of the training characteristics with total race time including the split times is reported in Table 2. A small effect size was found between weekly swimming hours, weekly swimming, cycling and running kilometres and total race time. The relationships between weekly swimming hours and time in the swimming split showed also a small effect size as well as the association between weekly running kilometres and time in the running split. A medium effect size was observed in the association between speed in swimming, running and cycling training with total race time, between weekly swimming kilometres and speed in swimming with time in the swimming split and between weekly cycling kilometres and speed in cycling with time in the cycling split. A large effect size was found in the association between speed in running during training and split time in the running section.

DISCUSSION

The hypothesis of this investigation was that anthropometric characteristics of male Ironman triathletes would be rather related to split time in the cycling section as physique of Ironman triathletes was similar to that of cyclists^[12]. We investigated the relationship between anthropometric and training characteristics using correlation analysis and their effect size; only associations with a medium effect size ($r = 0.24 - 0.36$) and large effect size ($r = 0.37$ or larger) will be considered relevant.

The association of anthropometric characteristics with race performance:

In contrast to our hypothesis, we assume that these recreational male Ironman triathletes seemed very similar to runners from an anthropometric point of view. Body mass, body mass index, the circumferences of limbs, the thicknesses of skin-folds and body fat were significantly and positively related to the split time of running. When we consider only the associations with a medium and large effect size, body mass and body mass index were related to both the total race time and the time in running split; the sum of skin-folds and percent body fat were associated with total race time and all split times. Likewise, the circumferences of the upper arm and the thigh were both related to the time in the running split. A relationship of these anthropometric variables with endurance performance times has already been described in runners over middle distances up to the marathon and in ultra-marathon running. Body mass^[26] and body mass index^[27] were related to performance in ultra-runners. There were several studies of runners showing an association of both skin-fold thicknesses and body fat with performance. Elite runners over 10,000 m^[28] and the marathon distance^[29] had low skin-fold thicknesses and low body fat. The sum of skin-folds was associated with performance in runners over 10,000 m^[28]. Arrese & Ostáriz^[30] showed high correlations between the front thigh and the medial calf skin-fold thickness and both the 1,500 m and the 10,000 m running time. However, the sum of skin-folds was not associated with performance for any of the distances. It seems that with increasing length of a

running event the sum of skin-fold thicknesses become more important. In marathon runners, all skin-fold thicknesses were significantly lower compared with runners over shorter distances^[32].

The relationship of the circumferences of both the upper arm and the thigh with time in the running split showed a medium effect size. Upper arm circumferences were related to race time in ultra-runners in multi-stage ultra-runs^[26,32] and thigh circumference was related to running performance over 800 m, 1,500 m and 5,000 m^[33]. Regarding our hypothesis that anthropometric characteristics would be related to split time in cycling, we found only an association between skin-fold thickness and body fat and cycling split time respectively. There were a few studies investigating the association of anthropometry with performance in cyclists and in which body mass seemed to be related to performance. Road cyclists with a lower body mass had an advantage in endurance cycling during climbing^[34]. This was confirmed in off-road cyclists^[35,36]. However, in track cyclists, no association was found between body mass and performance^[37]. Regarding the circumferences of limbs, in track cyclists, no significant correlation between the girth of extremities such as arm, thigh and calf and endurance performance had been found^[37]. No correlations were found between the skin-fold thicknesses and race performance in mountain bike cyclists either^[38]. A recent study comparing ultra-triathletes and ultra-runners concluded that ultra-triathletes were not similar to ultra-runners regarding anthropometric and training characteristics^[19]. In these Ironman triathletes, however, more anthropometric characteristics showed a medium to large effect size in association with the running split than with the other splits. This might also be in accordance with recent findings on ultra-triathletes, where running performance was associated with race time^[6]. Future studies should compare training and anthropometric characteristics between Ironman triathletes and marathon runners.

The association of training characteristics with race performance:

A further question was, whether volume and intensity of training might be of importance regarding race

performance in Ironman triathletes. We found a medium effect size in the association between the speed in swimming, cycling and running during training and total race time, between the weekly swimming kilometres and the speed in swimming training and the swimming split time, and between the weekly cycling kilometres and the speed of cycling training and the time in the cycling split. A large effect size was found in the relationship between the speed in running training and the time in the running split. The finding of a large effect size in the association between the speed in running training and the time in the running split would support the hypothesis that Ironman triathletes are close to runners. Besides, the anthropometric characteristics such as body mass, body mass index, circumferences of limbs, the sum of skin-folds and body fat were related to both the time in the running split and total race time.

According to O'Toole^[13] and Gulbin & Gaffney^[20], training distances appeared to be a more important factor for race success than training paces. This was supported by the findings of Hendy and Boyer^[39]. Specificity in the relationship between training and performance appeared to be supported especially by sports that rely more on the body, such as swimming and running, and less on equipment, such as cycling. In our subjects, however, both the speed in training and the weekly training kilometres showed a medium to large effect size with the corresponding split times. Moreover, in recent studies of swimmers, the speed during training, but not the volume of training, was related to race time^[40,41].

Limitations and implications for future research:

This study has examined a rather small sample (n=184) of recreational male Ironman triathletes considering the entire field of starters in an Ironman race. Our male athletes finished the race within 11:26 h:min. Professional male Ironman triathletes finish an Ironman within 8:30 h:min to 9:00 h:min, depending upon the environment and the course. We might assume that a larger study sample including both professional and recreational triathletes would show a large effect size in the association between training parameters and race time. The lower fitness level of recreational athletes compared with professional

athletes might have influenced our findings. Holly et al^[42] reported average weekly training volumes of 19 km of swimming, 590 km of cycling and 95 km of running for four top 15 competitors at the Ironman Hawaii. This is about two to three times the volume of our recreational triathletes.

CONCLUSION

The results of this study showed that lower body mass, lower body mass index and lower body fat were associated with both a faster Ironman race time and a faster running split in the race. Lower circumferences of upper arm and thigh were also related to a faster running split. From a practical point of view, athletes

with low body mass, low body fat and slim extremities will have an advantage to achieve a fast Ironman race time. Future studies should compare training and anthropometric characteristics between Ironman triathletes and marathon runners.

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Conflict of interests: None

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