Running performance not anthropometric factors is associated with race success in a Triple Iron Triathlon

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Abstract

OBJECTIVES: To investigate the influence of anthropometric parameters on race performance in ultra-endurance triathletes

DESIGN: Descriptive field study.

SETTING: The Triple Iron Triathlon Germany 2006 in Lensahn over 11.6 km swimming, 540 km cycling and 126.6 km running.

SUBJECTS: 17 male Caucasian triathletes (mean +/- SD, 39.2 +/- 7.5 years, 80.7 +/- 8.9 kg, 178 +/- 5 cm, BMI 25.4 +/- 2.4 kg/m2).

INTERVENTIONS: None.

Main Outcome Measurements: Determination of body mass, body height, skin fold thicknesses, circumferences of extremities as well as calculation of body mass index (BMI), skeletal muscle mass (SM), percent SM (%SM) and percent body fat (%BF) in order to correlate measured and calculated anthropometric parameters with race performance.

RESULTS: Body mass, body height, skin fold thicknesses, circumferences of extremities, BMI, %SM and %BF had no effect (p>0.05) on race performance. The squared correlation coefficient between the race time and the anthropometric properties limb circumferences, BMI, %SM and %BF was always lower than 0.03. The best correlation was shown between running time and total race time ($r^2$=0.87) as well as cycling time and total race time ($r^2$=0.62). The lowest correlation was shown between swimming time and total race time ($r^2$=0.04).

CONCLUSIONS: There is no association of anthropometric parameters with race performance in ultra-endurance triathletes. Running performance before cycling performance seems to be the most important factor in order to be successful in a Triple Iron Triathlon. Swimming performance seems to be of low importance.
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**Running performance not anthropometric factors is associated with race success in a Triple Iron Triathlon**

**Key words:** body mass index – anthropometry – skeletal muscle mass – fat mass – ultra-endurance
Abstract

Objectives: To investigate the influence of anthropometric parameters on race performance in ultra-endurance triathletes. Design: Descriptive field study. Setting: The Triple Iron Triathlon Germany 2006 in Lensahn over 11.6 km swimming, 540 km cycling and 126.6 km running. Subjects: 17 male Caucasian triathletes (mean ± SD, 39.2 ± 7.5 years, 80.7 ± 8.9 kg, 178 ± 5 cm, BMI 25.4 ± 2.4 kg/m²).

Interventions: None. Main Outcome Measurements: Determination of body mass, body height, skin fold thicknesses, circumferences of extremities as well as calculation of body mass index (BMI), skeletal muscle mass (SM), percent SM (%SM) and percent body fat (%BF) in order to correlate measured and calculated anthropometric parameters with race performance. Results: Body mass, body height, skin fold thicknesses, circumferences of extremities, BMI, %SM and %BF had no effect (p>0.05) on race performance. No significant correlation (p>0.05) was observed between total race time and any of the directly measured and calculated anthropometric properties. A significant correlation (p<0.05) was observed between total race time and both running time (r²=0.87) and cycling time (r²=0.62). In contrast, no significant correlation (p>0.05) was shown between swimming time and total race time. Conclusions: There is no significant association between anthropometric parameters and race performance in ultra-endurance triathletes. Running performance rather than cycling performance seems to be the most important factor in order to be successful in a Triple Iron Triathlon. Swimming performance seems to be of low importance.
Introduction

In endurance performance, an abundant variety of different factors influencing performance have been found. Apart from physiological parameters, numerous anthropometric parameters show an effect on endurance performances in runners and triathletes such as body mass [1, 2], body mass index [3], body fat [3], length of the upper leg [4], length of limbs [5], body height [1, 6], circumference of the thigh [4], total skin fold [1] and skin fold thickness of the lower limb [7, 8]. Anthropometric properties and exercise performance during short and middle distance running, marathons and triathlons over an Ironman distance have been previously investigated [2, 7, 8], but data from ultra-distance performances is rare. In this current investigation, the anthropometric data of 17 successful finishers of the Triple Iron Triathlon Germany 2006 over 11.4 km swimming, 540 km cycling and 126.6 km running were analysed in respect of their association with race performance. We expected that a low BMI would have an effect on race performance. Furthermore, we assumed that a high percentage of body fat may impair race performance. The aim of the current study was to explore the anthropometric factors that are predominantly responsible for race success during an ultra-triathlon over the 3 times Ironman distance.

Subjects and Methods

Subjects
All participants of the Triple Iron Triathlon Germany 2006 in Lensahn, Schleswig-Holstein, Germany, were contacted by a separate newsletter from the organiser 3 months before the race, and asked to participate in our investigation. Twenty-nine Caucasian triathletes (one woman, 28 men) intended to start. Twenty-five athletes (one woman, 24 men) entered the race, the only woman and 21 men finished the race successfully within the time limit. Twenty-two male athletes entered our study. They all gave their informed written consent. From these subjects, 17 male triathletes (mean ± SD, age 39.2 ± 7.5 years, body mass 80.7 ± 8.9 kg, body height 178 ± 5 cm, BMI 25.4 ± 2.4 kg/m²) finished the race successfully within the time limit whereas 5 athletes (mean ± SD, age 41.8 ± 12.2 years, body mass 85.8 ± 9.1 kg, body height 179 ± 3 cm, BMI 26.7 ± 3.0 kg/m²) had to give up due to medical reasons. The successful finishers trained 18.9 ± 7.4 (6 to 33) hours per week in the preparation for this race and could show an average experience of 18 (2 to 55) finished ultra-endurance races of 24 hours and more before the start.

The race
From 28th July to 30th July 2006, the 15th edition of the Triple Iron Triathlon Germany 2006 in Lensahn, Schleswig-Holstein, Germany, over 11.6 km swimming, 540 km cycling and 126.6 km running took place. On Thursday 28th July at 07:00 a.m., the race started. The swimming was in a heated outdoor pool of 50 m with a constant temperature of 25°C Celsius and wet suits were allowed. After passing the transition area, 67 laps of a hilly course of 8 km had to be cycled in the surroundings of the town. After cycling, athletes had to change to the run course of 96 laps of 1.31 flat km in the town of Lensahn. The cycling was nearly free of road traffic and the running course was completely free of traffic and illuminated during the night. All athletes had their own support crew for nutrition and changes of equipment. The athletes had to arrive at the finish line within 58 h. The weather on the first day was cloudy and no rain was falling with a maximal temperature of 28°C Celsius. In the first night toward the sunrise, cold and rain appeared. The second day was initially cloudy, then in the afternoon the sun appeared and the temperature rose to maximally 28°C Celsius.

Measurements and calculations
In the evening before the start, body mass, circumference of upper arm, thigh and calf as well as skin fold thickness at 8 regions were measured. Body mass was measured with a commercial scale (Beurer BF 15, Beurer GmbH, Ulm, Germany) to the nearest 0.1 kg. Circumference of the upper arm and calf were measured at the largest circumference of the limb; circumference at the thigh was determined 20 cm above the upper pole of the patella.
All circumferences were measured to the nearest 0.1 cm. Skin fold thicknesses of chest, midaxillary (vertical), triceps, subscapular, abdominal (vertical), suprailiac (at anterior axillary), thigh and calf were measured with a skin fold calliper (GPM-Hautfaltenmessgerät, Siber & Hegner, Zurich, Switzerland) to the nearest 0.2 mm. Skin fold thicknesses and circumferences of the extremities were measured on the right side of the body, according to Lee et al.[9] Every measurement was taken by the same person, 3 times, and then the mean value was used for calculation. Skeletal muscle mass (SM) was calculated using the following formula: SM = Ht x (0.00744 x CAG$^2$ + 0.00088 x CTG$^2$ + 0.00441 x CCG$^2$) + 2.4 x sex – 0.048 x age + race + 7.8, where Ht = height, CAG = skin fold-corrected upper arm girth, CTG = skin fold-corrected thigh girth, CCG = skin fold-corrected calf girth, sex = 1 for male, race = 0 for white, according to Lee et al.[9] Percent skeletal muscle mass (%SM) was achieved by dividing SM by BM and multiplying by 100%. Percent of body fat (%BF) was calculated using the following formula: %BF = 0.465 + 0.180(ΣSF) - 0.0002406(ΣSF)$^2$ + 0.0661(age), where ΣSF = sum of skin fold thickness of chest, midaxillary, triceps, subscapular, abdomen, suprailiac and thigh mean, according to Ball et al.[10] Fat mass was calculated from body mass and %BF.

**Statistical analysis**

Directly measured (body mass, height, skin fold thicknesses, limb circumferences) and calculated (BMI, %BF, %SM) anthropometric parameters were correlated with total race times as well as with the race time of the single disciplines. Statistical analysis was performed with the R software package[11]. Spearman's rank correlation analysis was used to look for the relevant factors of running time. A rank based test was used as not all parameters are normally distributed. No regression analysis was used as the aim of the current study was to explore the performance relevant anthropometric properties rather than to predict athletes’ performance in future competitions. The tested factors are the direct measured anthropometric properties, the calculated anthropometric properties, as well as the competition times of the single disciplines. Furthermore, anthropometric differences between finishers (n=17) and non-finishers (n=5) were compared for with the 'Mann-Whitney' test. No correction for multiple statistical comparisons was used because our study had to be an exploratory investigation and not one in which specific hypotheses were tested on the basis of pre-existing data.

**Results**

Table 1 shows the anthropometric data of the successful finishers before the race.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Pre race</th>
<th>ttot</th>
<th>tswim</th>
<th>tcycle</th>
<th>trun</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body mass (kg)</td>
<td>80.7 (8.9)</td>
<td>0.090</td>
<td>0.014</td>
<td>0.047</td>
<td>0.124</td>
</tr>
<tr>
<td>C upper arm (cm)</td>
<td>27.6 (1.9)</td>
<td>0.026</td>
<td>0.007</td>
<td>0.033</td>
<td>0.056</td>
</tr>
<tr>
<td>C thigh (cm)</td>
<td>53.0 (3.6)</td>
<td>0.027</td>
<td>0.063</td>
<td>0.003</td>
<td>0.028</td>
</tr>
<tr>
<td>C calf (cm)</td>
<td>36.7 (2.5)</td>
<td>0.060</td>
<td>0.001</td>
<td>0.031</td>
<td>0.021</td>
</tr>
<tr>
<td>SF pectoral (mm)</td>
<td>5.1 (1.6)</td>
<td>0.067</td>
<td>0.110</td>
<td>0.007</td>
<td>0.125</td>
</tr>
<tr>
<td>SF axillar (mm)</td>
<td>7.7 (2.4)</td>
<td>0.006</td>
<td>0.114</td>
<td>0.066</td>
<td>0.015</td>
</tr>
<tr>
<td>SF triceps (mm)</td>
<td>8.9 (3.8)</td>
<td>0.047</td>
<td>0.068</td>
<td>0.159</td>
<td>0.008</td>
</tr>
<tr>
<td>SF subscapular (mm)</td>
<td>10.1 (2.2)</td>
<td>0.002</td>
<td>0.205</td>
<td>0.159</td>
<td>0.021</td>
</tr>
<tr>
<td>SF abdominal (mm)</td>
<td>13.9 (6.4)</td>
<td>0.000</td>
<td>0.092</td>
<td>0.004</td>
<td>&lt;0.000</td>
</tr>
<tr>
<td>SF suprailiacal (mm)</td>
<td>12.7 (6.0)</td>
<td>0.020</td>
<td>0.088</td>
<td>0.031</td>
<td>0.054</td>
</tr>
<tr>
<td>SF thigh (mm)</td>
<td>11.5 (3.7)</td>
<td>0.027</td>
<td>0.008</td>
<td>&lt;0.000</td>
<td>0.018</td>
</tr>
<tr>
<td>SF calf (mm)</td>
<td>8.5 (2.2)</td>
<td>0.071</td>
<td>0.070</td>
<td>0.006</td>
<td>&lt;0.000</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>25.4 (2.4)</td>
<td>0.003</td>
<td>0.010</td>
<td>0.067</td>
<td>&lt;0.000</td>
</tr>
<tr>
<td>Skeletal muscle mass (SM) (kg)</td>
<td>40.0 (3.8)</td>
<td>0.032</td>
<td>0.017</td>
<td>0.007</td>
<td>0.097</td>
</tr>
<tr>
<td>Percent body fat (%BF) (%)</td>
<td>14.4 (3.2)</td>
<td>0.014</td>
<td>0.100</td>
<td>0.016</td>
<td>0.037</td>
</tr>
</tbody>
</table>
Table 1: Anthropometric properties of the athletes before the start of the race and the square
correlation coefficient with total competition time \( (t_{tot}) \) as well as with discipline time \( (t_{swim}, t_{cycles}, t_{run}) \).
The parameters are grouped as directly measured properties (body mass, body height, average skin
fold thickness, skin fold corrected circumferences of extremities) and calculated properties (BMI, SM,
\%BF) as used for the multiple regression analysis. \( C = \) circumference, \( SF = \) skin fold thickness.
Values are given as mean (SD).

No significant (\( p>0.05 \)) differences of anthropometric parameters were observed between finishers and
non-finishers. The winner finished the race in 34:33:54 h:min:s, the last official finisher arrived after
54:24:27 h:min:s at the finish line. The fastest time in swimming was 3:04:12 h:min:s, the fastest time
in cycling 17:16:38 h:min:s and the fastest time in running 13:13:12 h:min:s. Race time is not
significantly correlated (\( p>0.05 \)) with the directly measured anthropometric properties (body height,
body mass and the skin fold corrected limb circumferences), and the calculated anthropometric
properties BMI, \%BF, and \%SM (Table 1). The squared correlation coefficient between the race time
and the anthropometric properties limb circumferences, BMI, \% skeletal muscle mass and \% fat mass
is always lower than 0.03 with the exception of the suprailiacal skin fold. Figure 1 shows the
correlation matrix of the split times for swimming, cycling and running. Race time is significantly
correlated (\( p<0.05 \)) with running time \( (r^2=0.87) \) and cycling time \( (r^2=0.62) \). However, total race time is
not significantly correlated (\( p<0.05 \)) with swimming time.

Discussion

The main finding of our investigation is the fact that we cannot confirm any of the previously found
anthropometric factors of runners and triathletes such as body mass [1, 2], body mass index [3], body
fat [3], length of the upper leg [4], length of limbs [5], body height [1, 6], circumference of the thigh
[4], total skin fold [1] and skin fold thickness of the lower limb [7, 8] in this study group of successful
finishers in a Triple Iron Triathlon. But it seems that the performance in the running and cycling split
are the most important factors to be successful in ultra-endurance triathlons whereas swimming
performance seems to be of low importance.

Anthropometric factors in triathletes and runners

In triathletes, other morphologic factors seem to be of importance compared to the above mentioned
parameters. Landers et al. found that robustness, adiposity, segmental length of limbs and skeletal
muscle mass are of importance.[5] But also in triathletes, an influence of body fat on race performance
is known. In recent studies, successful elite triathletes are described as tall, of average-to-light weight
and with low levels of body fat.[12] In an Ironman triathlon, starting body weight is significantly
related to total finishing time and also to cycling and running time.[2] O’Toole et al. concluded from
their study, that male triathletes are similar to cyclists.[13] They compared triathletes with swimmers,
cyclists and runners. A comparison of height, weight, and percent body fat of these triathletes with
elite swimmers, cyclists and runners showed the physique of triathletes to be most similar to that of
cyclists. But comparing the highest oxygen uptake attained at maximal exercise in any one of the 3
exercise modes, male triathletes were comparable to swimmers, but have a lower aerobic capacity than
cyclists or distance runners.

Looking at our results (Figure 1) with ultra-endurance triathletes, running performance has a higher
impact on total race performance than cycling performance. Swimming performance seems to have no
effect on total race performance in a triathlon, as already shown by Dengel et al.[14] They could show
in a triathlon over a 1.2 mile swim, 56 mile cycle and 13.1 mile run, that swimming time is not related
to overall triathlon time. Ultra-endurance triathletes seem to be nearer to ultra-runners than to cyclists
or swimmers. As shown in figure 1, running time has the most important impact on total race time
before cycling and swimming time. Interestingly, swimming required 8.6 (1.4) \% of total race time,
cycling 48.5 (2.7) \% and running 43.6 (3.7) \%. Although running performance has a higher impact on
total race performance than cycling, athletes expend more time on cycling than on running during the
race.
Individual cycling times varied from 1,036 to 1,527 min (variation coefficient 11.1 %) with an average of 1,339 (148) min and running time varied from 792 to 1,682 min (variation coefficient 18.4%) with an average of 1,215 (224) min. Swimming variation coefficient was 12.5%, variation coefficient of total race time was 11.7 %. There must be larger individual differences in running compared to cycling, probably related to fatigue and exhaustion during the run. We presume that those athletes who were better prepared for running were able to make the difference in the running section. When cycling on flat ground, air resistance is dominating and is about proportional to the square of speed. In running, power (energy expenditure) is rather linear proportional to speed. From this biomechanical point of view it obvious that running should also have more impact on race time than cycling if time requirements for both disciplines were equal.

Also for short distance triathlon, the only significant predictor of overall triathlon race time is velocity in running at ventilatory threshold.[15] Millet et al. demonstrated that over short distances triathletes have a faster swim time but could not exhibit different maximal or submaximal characteristics in cycling and running compared to long distance triathletes.[16] In triathletes, there is no ideal or unique anthropometric profile with respect to performance [17], and training parameters seem to be of more importance than anthropometric measures in the prediction of race performance [1, 18]. For runners, other factors are also discussed. In middle and long distance runners, the length of the upper leg and thigh girth are related to performance [4] and in marathon runners different physiological parameters can explain the variance in marathon times amongst elite runners.[19] In marathon finishers, the longest mileage covered per training session is the best predictor for a successful completion of a marathon [20] and total training spent at low intensities seems to be associated with improved performance during highly intense events [21]. But an upper limit exists in training volume, above which there are no more improvements.[22]

**Body mass, body mass index and running performance**

From the above mentioned anthropometric parameters, the effects of body mass and BMI on performance have been investigated in several studies, especially in runners. The positive effect of BMI on performance is known in African endurance athletes. African runners are smaller [23, 24] and less heavy than Caucasian runners [23, 25]. The BMI of African runners is lower than in Caucasian runners. Kenyan runners have a BMI of 19.2 kg/m² compared to 20.6 kg/m² for the best Scandinavian runners [26] and Eritrean runners have a BMI of 18.9 kg/m² in contrast to 20.5 kg/m² for elite Spanish runners [27]. In contrast to these studies, Coetzer et al. found, that the African athletes’ smaller body mass had no effect on running performance over 5 km.[28] The superior distance running performance of the African athletes was associated with lower blood lactate concentrations during exercise. It is supposed that the lower BMI [29] and the smaller body size are of importance for the better performance of the African runners [30]. Marino et al. could demonstrate in their study, that the smaller body mass enables African runners to compete faster in a warm environment (35° C), because these runners seem to have a greater capacity for heat loss in hot environmental conditions.[30] Apart from African runners, a relationship also exists in Caucasian female marathon runners between BMI and race performance. The marathon race times for these runners is positively correlated to BMI.[3]. The absolute value of the BMI seems to be of importance. The BMI of our ultra-triathletes is higher than the BMI of Kenyan runners. Our triathletes have a BMI of 25.4 kg/m² (Table 1), which is higher than the BMI of young Kenyan runners with a BMI of 18.6 kg/m² [31] or adult Kenyan runners with 19.2 kg/m² [26]. The lower limb is also different in African runners compared to Caucasian runners. When Senegalese and Italian runners are compared, African runners have longer and lighter legs [32] and Eritrean runners have a longer lower leg than Spanish athletes in long distance running [27]. It is supposed that the lower BMI [31] and the smaller body size are of importance for the better performance of the African runners [30].

**Influence of body fat and skin fold thickness on performance in runners**

It is known from several studies that body fat has an influence on performances in runners. An excess of subcutaneous adipose tissue increases body mass, requires an increased muscular effort and therefore an increased energy expenditure. In former studies it has been shown that physical performance is negatively related to body fat and positively related to skeletal muscle mass [33, 34]. This could be confirmed in a recently published study.
The loss of body fat is specific to selected muscle groups used during training, and race performance is enhanced with decreased skin fold thickness at the lower limb.[8] Body fat seems to have a special influence in runners, especially in African runners. They have a thinner skin fold at the legs and arms [25] suggesting a smaller mass of adipose subcutaneous tissue. In other studies, the influence of body fat on race performance is controversially discussed. Whilst Hagan et al. found a positive correlation between marathon performance time and body fat [3], in female marathon runners, the percentage of body fat does not correlate with the finish time [18]. In several older, and again in recently published studies, the effect of skin fold thickness on running performance was investigated. In runners, decreased skin fold thicknesses in the lower limbs are described; this may be particularly useful in predicting running performance [8]. They found an association between the decrease in thigh skin fold thickness and improvement in performance and in the study of Bale et al. total skin fold among other parameters such as type and frequency of training and the number of years running were the best predictors of running performance and success at 10,000 m.[1] Arrese & Ostariz showed a high correlation between the thigh and calf skin fold and 1,500 m as well as 10,000 m run time.[7]

There are 2 major differences in the studies of Bale et al. [1], Legaz & Eston [8] and Arrese & Ostariz [7] compared to our study. Firstly, in their studies, running performances of 10,000 m and shorter were investigated. In contrast, our ultra-triathletes had to run a total distance of 126.6 km. Secondly, the measured skin fold thicknesses of the lower limb seem to be different. Ultra-triathletes seem to have thicker skin folds (Table 1) than runners over shorter distances. Our ultra-triathletes had a skin fold thickness of 11.5 ± 3.7 mm at the thigh and 8.5 ± 2.2 mm at the calf compared to 9.4 ± 4.2 mm at the thigh and 4.6 ± 1.3 mm in the calf of the runners in the study of Legaz & Eston.[8] Probably the average training volume of 18.9 ± 7.4 hours per week of our ultra-triathletes is too low compared to classical marathon runners.[20, 22] The length of the running race seems to be of importance for the correlation between skin fold thickness and race performance. Arrese & Ostariz could show that marathon runners have a lower sum of 6 skin folds than runners of distances up to 10,000 m.[7] They conclude that marathon runners undertake a higher training volume and that in marathon running fat metabolism prevails in training and competition. Interestingly, our ultra-triathletes have, with 65.5 mm (Table 1), a clearly higher sum of six skin folds compared to the marathon runners of Arrese & Ostariz with 44.4 mm. The value of 65.5 mm for our triathletes is near the value of 61.7 mm for the 3,000 m runners of Arrese & Ostariz.[7].

**Conclusion**

In an ultra-triathlon over 11.6 km swimming, 540 km cycling and 126.6 km running, there is no association between the anthropometric parameters body mass, body height, skin fold thickness, circumference of extremities, %SM and %BF with total race time and split times for swimming, cycling and running. It seems that running performance is the most important factor before cycling performance in order to be successful in an ultra-endurance triathlon over 3 times the Ironman distance. Swimming performance seems to be of low importance. Triathletes may have a higher variability in body anthropometry than other endurance athletes because they have to train and perform 3 different disciplines. We would welcome studies about the influence of anthropometry on endurance and race performance with triathletes especially over the Ironman distance.

**Acknowledgments**

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References


Figure 1: The correlation matrix of the split times and total race time is shown. In the upper panels the squared correlation coefficients are shown. The best correlation is shown between running time and total competition time. The lowest correlation is shown between swimming time and running time.
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The authors have no competing interest.

**What is already known on this topic:** In Ironman triathlon, starting body weight is significantly related to total finishing time and also to cycling and running time.

**What this study adds:** In Triple Iron triathlon, anthropometric parameters show no association with race performance, but running performance is associated with race success.