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Influence of anthropometry on race performance in ultra-endurance triathletes in the longest triathlon in North America

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Abstract

Background: Little is known about the effects of anthropometry on race performance in ultra-endurance athletes. **Research question:** The investigation of the influence of anthropometric parameters on race performance in ultra-endurance triathletes in the longest triathlon in North America. **Type of study:** Descriptive field study. **Methods:** Body mass, body height, length of lower limbs, skinfold thicknesses, circumferences of extremities (as well as calculation of BMI), percent skeletal muscle mass (%SM) and percent body fat (%BF) were determined in the 8 male starters of the Virginia Triple Iron Triathlon 2006 in the USA. This race is the longest triathlon in North America, where athletes have to perform a 11.4 km swim, 540 km cycle ride and 126.6 km run within 68 hours. The measured and calculated anthropometric parameters were correlated with race performance in order to find factors that influence race performance in ultra-endurance triathletes. **Results:** In the 5 successful finishers of the race, race time was not significantly influenced by the directly measured anthropometric properties of body height, length of limbs, body mass, average skinfold thickness, and the limb perimeters of thigh, calf and upper arm ($p>0.05$). Furthermore, no significant influence was observed between race time and the calculated parameters BMI, %BF and %SM ($p>0.05$). **Conclusions:** In the Virginia Triple Iron Triathlon 2006, no influence was observed from body mass, body height, length of limbs, skinfold thickness, perimeters of extremities, BMI, %SM and %BF on race performance in the only 5 successful finishers. **Keywords:** body mass index, BMI, skeletal muscle mass, fat mass, ultra-endurance event, extreme sports, triathlon

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Introduction

From the literature, an abundant variety of factors influencing performance in endurance exercise have been shown to exist. Apart from the physiological parameters, a variety of anthropometric parameters, such as body mass [1], body mass index [2], body fat [2], height [1, 3], length of the upper leg [4], length of limbs [5], circumference of thigh [4,] total skinfold [1], and skinfold thickness of the lower limb [6, 7], have been shown to influence endurance performance in runners. In swimmers, fat mass [8], upper extremity length [9] and height [9, 10] seem to influence performance, but there might be differences based on gender. Whereas in female swimmers, height, body weight, percent body fat and fat-free weight have an effect on swimming performance, these effects have not been shown in male swimmers [11]. In cyclists, sprint cyclists and time-trialists have been compared (1000m to track time trial). Sprint cyclists were heavier and had larger chest-, arm-, thigh- and calf girths than endurance cyclists [12]. Time trialists were taller and had longer legs than the sprint cyclists[13]. In triathletes, body mass [14] and length of limbs [5] were shown to effect performance.

Data from ultra-endurance athletes is rare and often only found in case reports. In this current investigation, anthropometric data of the 5 successful finishers of the Virginia Triple Iron Triathlon 2006, the longest triathlon in North America, were analysed with respect to their influence on the total race time. It was expected that BMI, as well as skeletal muscle mass, were important factors of exercise performance. Furthermore, it was assumed that relative fat mass proportion might impair race performance.

Subjects and methods

Subjects

Three months prior to the race, all participants in the Virginia Triple Iron Triathlon 2006, the longest triathlon in North America, were contacted by means of a separate newsletter in which they were asked to participate in the study. Twelve male Caucasian ultra-triathletes and one female Caucasian ultra-triathlete entered to take part in the race, but only 8 males and the only female started in the race. However, only 5 males and the only [•]female athlete finished successfully within the time limit. All 8 male racers participated in the investigation and all gave their informed written consent. Five athletes (mean ± SD, 44.4 ± 13.4 years, 81.4 ± 11.1 kg, 181 ± 6 cm, BMI 24.5 ± 1.9 kg/m^2) finished the race within the time limit. The 3 unsuccessful starters had to give up the race during the cycling section because of the cold weather. The successful athletes trained 25 ± 8 hours per week, varying from 13 to 35 hours, to prepare for this race. They had an average experience of 24 extreme endurance races of 24-hours or longer, varying between 13 to 52 completed races, prior to this event.

The race

The Virginia Triple Iron Triathlon is the longest and the toughest ultra-endurance triathlon in North America, where athletes have to cover 11.4km of swimming, 540km of cycling and 126.6km of running within 68 hours. On the evening of 5 October 2006, the race instructions for the participants were given at the beach café in Lake Anna State Park, Virginia, USA, close to the start of the race, which would be on the following morning at 07h00. The swim took place in Lake Anna, with a temperature of 23° Celsius. Wetsuits were allowed. Athletes had to swim 36 loops of 317m each in order to finish 11.4km. The cycling section of the race was on a hilly section in the Lake Anna State Park, and drafting was prohibited. Athletes had to cycle 69 loops of 7.8km each in order to finish the 540km ride. After cycling, the athletes had to run over a hilly running course of 39 loops of 3.24km each to cover the total running distance of 126.6km. The participants were allowed to use all the clothing that they required, bicycles, and any other equipment deemed necessary. They had their own support crews to assist with the changes of clothing and equipment, and to provide them with nutrition. Throughout the entire race, the weather was cold, with continuous rain. It began to rain during the night, prior to the start of the race. The temperature during the day rose maximally

[•] The results for the female athlete who completed the race have not been included because she indicated that she was not interested in being part of the study.

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to 12° Celsius and at night, dropped to 8° Celsius.

Measurements and calculations

The evening prior to the start of the race the following measurements were taken: body mass, length of the lower limbs, perimeter of upper arm, thigh and calf, as well as skinfold thickness from 8 regions. The length of the upper leg was measured from *Trochanter major* to *Meniscus lateralis*; the length of the lower leg from *Meniscus lateralis* to *Malleolus lateralis* of the right leg to the nearest 0.1cm. The circumference of the upper arm and calf were measured at the largest perimeter of the limb; at the thigh 20cm above the upper pole of the patella to the nearest 0.1cm. Skinfold thickness of the chest, midaxillary (vertical), triceps, subscapular, abdominal (vertical), suprailiac (at anterior axillary), thigh and calf were measured with a skinfold calliper (GPM-skinfold calliper, Siber & Hegner, Zurich, Switzerland) to the nearest 0.2mm.

Skinfold thicknesses and circumferences of the extremities were measured on the right side of the body, according to the study of Lee et al.[15]. Each measurement was taken by the same person, repeated 3 times, and then the mean value was used for calculation.

Skeletal muscle mass (SM) was calculated using the following formula: $SM = Ht \times (0.00744 \times CAG^2 + 0.00088 \times CTG^2 + 0.00441 \times CCG^2) + 2.4 \times sex - 0.048 \times age + race + 7.8$, where Ht = height, CAG = skinfold-corrected upper arm girth, CTG = skinfold-corrected thigh girth, CCG = skinfold corrected calf girth, sex = 1 for male, race = 0 for White, according to the study of Lee et al.[15]. Percentage body fat (%BF) was calculated using the following formula: $\%BF = 0.465 + 0.180(\Sigma 7SF) - 0.0002406(\Sigma 7SF)^2 + 0.0661(age)$, where $\Sigma 7SF$ = sum of skinfold thickness of chest, midaxillary, triceps, subscapular, abdomen, suprailiac and thigh mean [16].

Statistical analysis

Measured and calculated anthropometric parameters were correlated with race time. Statistical analysis was performed with the R software package[17]. Forward selection of the predictor variables was used in the multiple regression analysis to identify the performance-relevant anthropometric parameters. As anthropometric properties can be described by several dependent parameters, the directly measured predictor variables (body mass, body height, mean skinfold thickness, length of the lower limbs and the limb perimeters of the calf, the thigh, and the upper arm) and the calculated predictor values (BMI, percent fat mass, and percent skeletal muscle mass) were separated into 2 independent models. For all statistical tests, the significance level was set to 0.05.

Results

Average race time for the 5 successful male finishers was 58 hours (Table 1).

Table 1: Performance of the 5 athletes in swimming, cycling, running and in total. Results are presented as mean and (SD)

Subject	Swimming time in hours (h) and minutes (min)	Cycling time in hours (h) and minutes (min)	Running time in hours (h) and minutes (min)	Total time in hours (h) and minutes (min)
1	3 h 36 min	26 h 27 min	22 h 19 min	52 h 58 min
2	5 h 44 min	32 h 48 min	16 h 13 min	55 h 31 min
3	4 h 12 min	30 h 51 min	21 h 14 min	57 h 6 min
4	6 h 37 min	26 h 50 min	25 h 53 min	59 h 51 min
5	4 h 30 min	38 h 2 min	24 h 2 min	67 h 22 min
Mean	4.4 h 31.8 min	30.4 h 35.6 min	21 h 20 min	58 h 33 min
(SD)	1.1 h 12.1 min	5 h 21 min	3.5 h 20 min	5.6 h 21 min

The average speed in the swimming section of the race was 2.6km/h, in the cycling 17.8km/h and in the running 6km/h.

Table 2 shows the anthropometric data of the successful finishers before the race.

Table 2: Anthropometric properties of the athletes before the start of the race. The parameters are grouped as directly measured properties (body mass, height, average skinfold thickness, circumference of extremities) and calculated properties (BMI, SM, %BF) as used for the multiple regression analysis. C = circumference, SF = skinfold thickness, L = length. Values are given as mean (SD).

Parameter	**Unit**	**Result**
Body mass	kg	83.8 (11.3)
Body height	m	1.82 (0.05)
L upper leg	cm	46.2 (2.0)
L lower leg	cm	42.9 (1.3)
L leg	cm	89.0 (3.0)
C upper arm	cm	31.4 (2.6)
C thigh	cm	56.2 (3.5)
C calf	cm	38.0 (1.8)
SF pectoral	mm	6.8 (3.7)
SF axillary	mm	9.0 (3.8)
SF triceps	mm	6.4 (1.5)
SF subscapular	mm	12.6 (8.1)
SF abdominal	mm	19.0 (11.1)
SF suprailiacal	mm	14.0 (8.2)
SF thigh	mm	7.8 (1.7)
SF calf	mm	7.8 (2.4)
BMI	kg/m^2	25.1 (2.3)
Skeletal muscle mass (SM)	kg	41.4 (4.9)
% Body fat (%BF)	%	15.4 (5.5)

The race time is not statistically significantly influenced by the directly measured anthropometric properties, body height, body mass, average skinfold thickness, and the limb perimeters of thigh, calf and upper arm (Figure 1), as well as length of the lower limbs (Figure 2) ($p>0.05$). Furthermore, no significant influence was observed between race time and the calculated parameters BMI, percent body fat (%BF) and percent skeletal muscle mass (%SM) (Figure 3) ($p>0.05$).

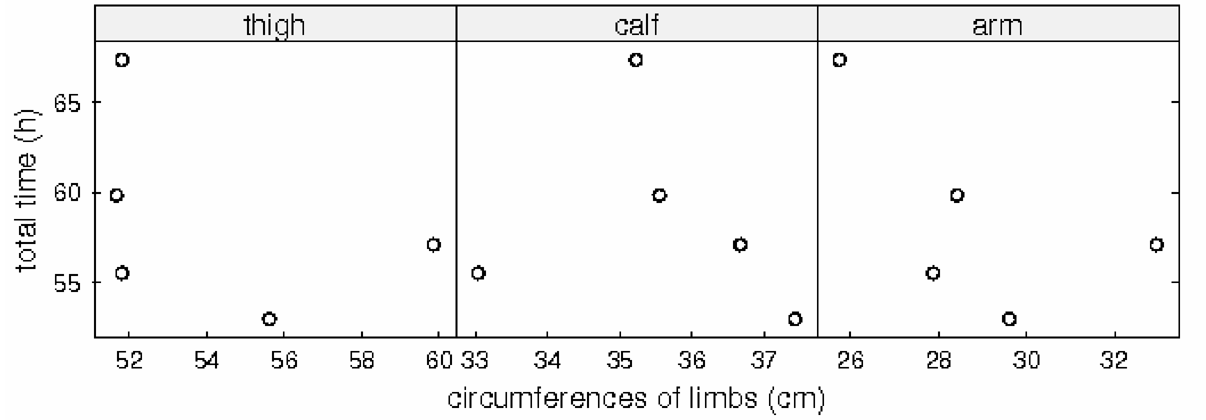

Figure 1: No significant influence was found between the running time and circumference of the limbs (upper arm, upper leg and lower leg) in the Virginia Triple Iron Triathlon 2006 (p>0.05).

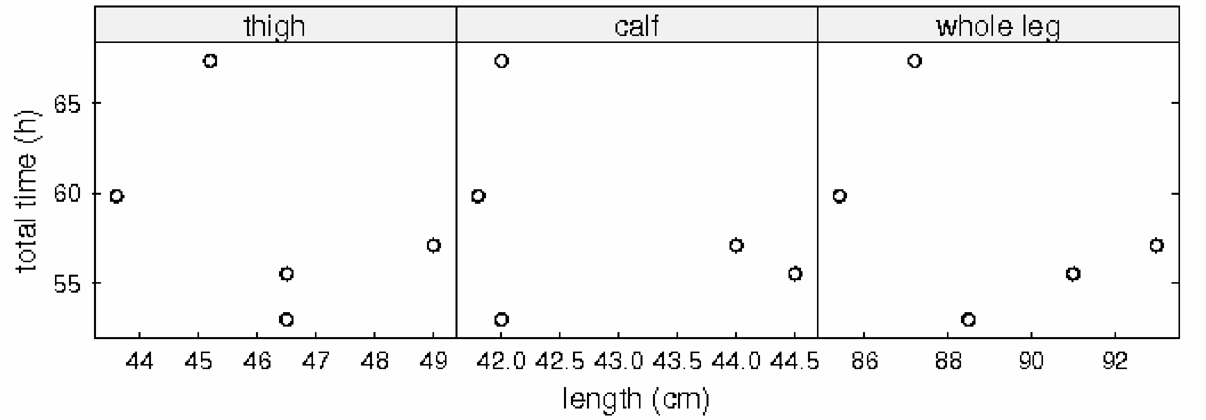

Figure 2: Length of the lower limb (upper leg, lower leg and whole leg) shows no influence on running time in the Virginia Triple Iron Triathlon 2006 (p>0.05).

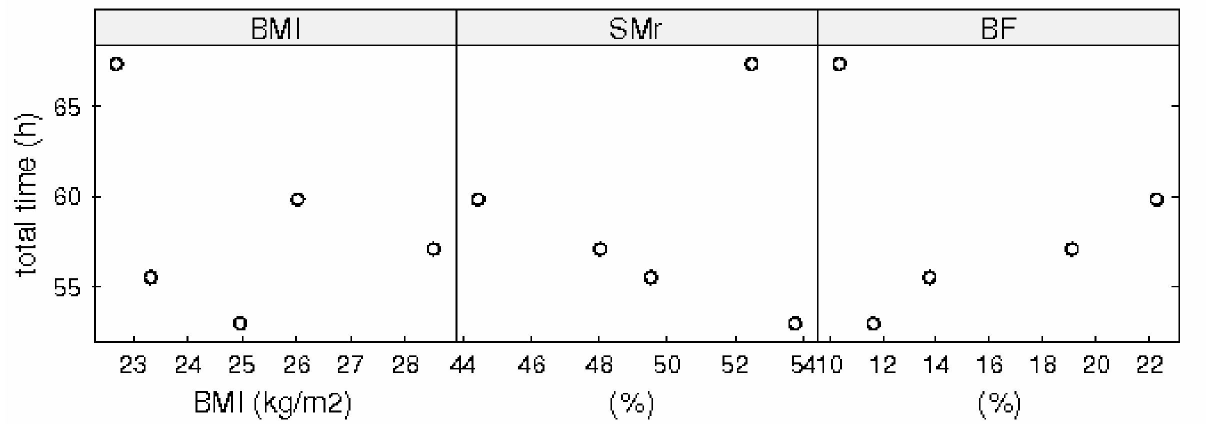

Figure 3: No significant influence was found between the running time and the calculated parameters BMI, percent skeletal muscle mass (%SM) and percent body fat (%BF) in the Virginia Triple Iron Triathlon 2006 (p>0.05).

Discussion

The main finding of this investigation is the fact that none of the previously found anthropometric factors, such as body fat [2], circumference of thigh [4], total skinfold thickness [1], BMI [2], body mass [1, 14], length of the upper leg [4], length of limbs [5], and skinfold thickness of the lower limb [6, 7] in endurance athletes can be confirmed in this limited group of the only 5 successful male finishers of the longest triathlon in North America in 2006. In contrast to the ultra-triathletes in this study, several anthropometric factors shown to influence performance have been found in runners, swimmers, cyclists and triathletes[1-13]. The influence of body mass, skinfold thicknesses and body fat is described in several studies with runners[1-7]. The present authors presume that there must be differences between triathletes, swimmers, cyclists and runners, or that this present study group, with the 5 successful finishers of the longest triathlon in the USA, was too small to find any statistically significant differences compared to the previously mentioned studies.

Body mass, BMI and running performance

The influence of body mass and BMI on performance is well known in long-distance runners, especially in African runners. African runners are smaller [18, 19] and lighter in weight than white runners [18, 20]. However, this could not be confirmed in the study of Rahmani et al. [21], although they only investigated the effect of body mass in sprinters.

The BMI of African long-distance runners is lower than that in Caucasian runners. The BMI of the Kenyan runners is 19.2 kg/m^2 compared to 20.6 kg/m^2 for the best Scandinavian runners [22]. When age, height, body mass and leg morphology were compared in Senegalese and Italian runners, African runners were shown to have longer and lighter legs [21].
It is supposed that the lower BMI [23] and the smaller body size were significant in relation to the better performance of the African runners [24]. Apart from the Kenyan runners, the relationship between BMI and race performance can also be found in white female marathon runners. The marathon race times for these runners is positively correlated to BMI [2]. The absolute value of the BMI may be important. The BMI of the ultra-triathletes in this present study is higher than the BMI of Kenyan runners. The triathletes in this present study have a BMI of 25.1 kg/m^2 (Table 2), which is higher than the BMI of young Kenyan runners, with a BMI of 18.6 kg/m [2, 25,] or adult Kenyan runners with 19.2 kg/m^2 [22].

Influence of body fat on performance in runners

It is known from several studies that appropriate sports-specific levels of relative fat and fat-free weight are beneficial to performance in endurance sport [2, 8]. Body fat has an influence on performance in runners [2]. An excess of adipose tissue requires an increased muscular effort and therefore increased energy expenditure [7]. In previous studies, it has been shown that physical performance is negatively related to body fat and positively related to skeletal muscle mass [26, 27]. This could be confirmed in a recent study [7]. The loss of body fat is specific to muscular groups used during training, and race performance is enhanced with decreased skinfold thickness in the lower limb [7]. Body fat seems to be significant in runners, especially African runners, and their performance. They have a thinner skinfold thickness in the legs and arms [20] suggesting a smaller mass of adipose subcutaneous tissue. In other studies, the influence of body fat on race performance is controversially discussed [2, 28, 31]. Whilst Hagan et al. found a positive correlation between marathon performance time and body fat [2], in female marathon runners, the percentage of body fat did not correlate with finish-time [28].

Skinfold thicknesses and their effect on running performance

In older and some recently published studies, the effect of skinfold thickness on running performance was investigated [1, 6, 7, 29, 30]. In runners, decreased skinfold thickness in the lower limb is described, which may be particularly useful in predicting running performances [7]. Legaz & Eston [7] found an association between the decrease in thigh skinfold thickness and improvement in performance, and in the study of Bale et al. [1] the total skinfold along with 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 000m. Arrese & Ostariz [6] showed a high correlation between the thigh and calf skinfolds and 1500m as well as 10 000m run times. In former studies, this influence was not described [29-31]. No differences were obvious in skinfold thickness among runners competing in classical distances ranging from 100m to 10 000m [31], Conley & Krähenbühl reported no significant relation between body fat or sum of skinfolds in an elite group of 10 000 m runners [29] and Kenney & Hodgson showed similar findings in 3000m steeplechase runners [30].

There are 2 major differences in the studies of Bale et al. [1], Legaz and Eston [7] and Arrese and Ostariz [6] compared to our study. Firstly, in their studies, running performance of 10 000m or less were investigated; in contrast, the ultra-triathletes in this study had to run a total distance of 126.6km. Secondly, the measured skinfold thicknesses of the lower limb seem to be different in runners (Legaz and Eston's study[7]) and ultra-triathletes. This study's ultra-triathletes seem to have thicker skinfolds than runners over shorter distances (Table 2). The ultra-triathletes had a skinfold thickness of 7.8 ± 1.7mm at the thigh and 7.8 ± 2.4mm at the calf compared to 9.4 ± 4.2mm at the thigh and 4.6 ± 1.3mm at the calf in the runners in the study of Legaz and Eston [7].

The length of the running race seems to be of importance for the correlation between skinfold thickness and race performance. Arrese and Ostariz [6] showed that marathon runners have a lower sum of 6 skinfolds than runners of distances up to 10 000m. They conclude that marathon runners undertake a higher training volume and that in marathon running fat metabolism prevails in training and competition. Interestingly, the ultra-athletes in this present study have (with 67.6mm) (Table 2)) a much higher sum of 6 skinfolds compared to the marathon runners in the study of Arrese and Ostariz [6], with 44.4mm. The value of 67.6mm for the ultra-triathletes in this study is close to the value of 61.7mm for the 3000m runners in the Arrese and Ostariz study[6].

Anthropometric factors in triathletes, cyclists and swimmers

Most of the above mentioned studies referring to the effect of anthropometry on performance have been undertaken with runners [1, 6, 7, 29, 30]. In triathletes, other morphologic factors like robustness, adiposity, segmental lengths and skeletal muscle mass [5] or economy of movement in swimming, cycling and running [32] seem to be of more importance than for runners [1, 6, 7, 29, 30].

Landers et al. [5] found that segmental length of limbs and skeletal muscle mass are of importance in triathletes, and that body fat influences their race performance [32]. In recent studies, successful elite triathletes are described with low levels of body fat [32]. In an Ironman triathlon, body weight at the start of the race is significantly related to total finishing time, and also to cycling and running time [14]. Triathletes are closer to swimmers than runners related to body composition and somatotype, as concluded in the study of Leake and Carter [33]. Landers et al. [5] concluded from their study that proportionally longer segmental leg lengths contributed to successful swimming performance in triathletes over the Olympic distance. When cyclists are compared, Foley et al [13] could show that sprint cyclists are shorter in height than endurance cyclists, and time trialists are taller than endurance cyclists. Sprint cyclists in particular are heavier and have larger girths for chest, arm, thigh and calf, than endurance cyclists [12].

Other aspects of anthropometric factors and training in runners and triathletes

For runners, other factors, such as length of limbs [4,5] and circumferences of limbs [4], are also discussed. In middle- and long-distance runners, the lengths 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 among elite runners [31]. In triathletes, there is no ideal or unique anthropometric profile with respect to performance [34], and training parameters seem to be of more importance than anthropometric measures in the prediction of performance [1, 28, 35]. Also, training seems to have en effect on performance in triathletes [33]. Leake and Carter [33] could show in their study with triathletes that, in comparison to swimmers and runners, training parameters were more important than anthropometric measures in the prediction of performance. The same results have been found in marathon runners. In marathon finishers, where the longest mileage covered per training session is the best predictor for the successful completion of a marathon [36], and total training at low intensities seems to be associated with improved performance during highly intense events [37]. But there is an upper limit in training volume, above which there are no further improvements [38].

Limitations of the present study

In this longest ultra-triathlon of the USA, only 8 athletes started the race and the small number of 5 male official finishers could be included in this investigation. This is a limiting factor with regard to the research question examining the influence of anthropometric parameters on race performance. In this study, anthropometric data shows that this had no effect on race performance. In contrast to small number of subjects in this present study, other studies that also examined anthropometric properties related to sports performance had greater numbers of subjects, for example, Arrese and Ostariz [6] had 184 top-class runners, and Legaz and Eston [7] had 35 athletes in total. One problem is that ultra-endurance races, like the Virginia Triple Iron Triathlon, attract only a few athletes. In addition, in this race, nearly half of the participants gave up during the race. As previously mentioned, in this particular race, the 3 unsuccessful athletes gave up as a result of the cold weather. When the BMI of the successful finishers (25.1 ± 2.3kg/m^2) is compared with the BMI of the unsuccessful finishers (23.2 ± 3.4kg/m^2), it can be seen that the successful finishers tended to be overweight compared with the unsuccessful athletes (Table 2). Probably the higher body mass was helpful for the successful finisher in the cold weather, and the unsuccessful finishers were too thin to cope with the cold. Skeletal muscle mass in the successful finishers was at 41. ± 14.9kg compared to 39.6 ± 6.0kg in the unsuccessful finishers, but percent body fat was the same for both groups (15.4 ± 5.5kg for the finishers compared with 15.4 ± 6.8 kg for the non-finishers). When percentage body fat was the same for both groups, fat mass was not a limiting factor for the non-finishers, but it was rather the lower skeletal muscle mass.

Conclusions

To summarise, in the Virginia Triple Iron Triathlon 2006 no correlation could be found between race performance and body mass, height, length of limbs, skinfold thickness, circumference of extremities, %SM and %BF in the small sample of the only 5 official finishers. It is presumed that the sample size was too small and studies with triathletes over Olympic and Ironman distances will be welcomed due to the fact that there seems to be insufficient literature on the influence of anthropometry on race performance in triathletes.

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