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A Comparison of Anthropometric and Training Characteristics among Recreational Male Ironman Triathletes and Ultra-Endurance Cyclists

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Abstract

The physique of Ironman triathletes was considered to be similar to that of cyclists. We intended to investigate differences and similarities in anthropometry and training between 83 Ironman triathletes competing in a qualifier for 'Ironman Hawaii' and 84 ultra-endurance cyclists competing in a qualifier for the 'Race across America'. The anthropometric and training characteristics were compared between these two groups of athletes; associations of anthropometric and training characteristics with race time were investigated using bi- and multi-variate analysis. The Ironman triathletes had shorter legs, lower circumferences of upper arm, thigh and calf and a lower skeletal muscle mass compared to the ultra-cyclists. The Ironman triathletes invested more weekly training hours but fewer weekly cycling hours than the ultra-cyclists; the ultra-cyclists completed more cycling kilometres per week. In the multi-variate analysis, the skin-fold thicknesses at abdominal ($P = 0.02$) and iliacal site ($P = 0.02$) as well as percent body fat ($P = 0.0008$) were associated with race time for the Ironman triathletes. The abdominal ($P = 0.003$) and the iliacal ($P = 0.02$) skin-fold thicknesses, percent body fat ($P = 0.001$) and cycling speed during training ($P = 0.01$) were related to cycling split time in the Ironman race. For the ultra-cyclists, percent body fat ($P = 0.04$) was related to race time. We concluded that anthropometry and training of Ironman triathletes were different when compared to ultra-endurance cyclists.

Key Words: ultra endurance, body fat, body mass, body composition

Introduction

The sports discipline triathlon consists of the three split disciplines swimming, cycling and running. It can be performed over the short or Olympic distance of 1.5 km swimming, 40 km cycling and 10 km running (39, 49), the Ironman distance of 3.8 km swimming, 180 km cycling and 42.2 km running (37, 38, 40) and longer distances such as the Triple Iron ultra-triathlon over 11.4 km swimming, 540 km cycling and 126.6 km running (14, 26) or the Deca Iron ultra-triathlon over 38 km swimming, 1,800 km cycling and 422 km running (11, 16, 18, 19, 24).

The Ironman distance is the most popular long-distance triathlon (37, 38). Since the first event held in 1978 in Hawaii, every year tens of thousands of triathletes compete in more than 20 Ironman races (http://ironman.com/events/ironman) for the 'Ironman

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Hawaii' (http://ironman.com/worldchampionship), where more than 1,700 triathletes start in the Ironman World Championship (37, 38). Competing and finishing an Ironman triathlon needs training and racing in three different disciplines where, apart from psychological (44, 48) and physiological (42, 43) variables, different characteristics of anthropometry (22, 29, 30, 43) and training (8, 29, 30, 41) might also be associated with race performance.

Although the Ironman distance is the most famous long-distance triathlon, there is little data regarding the association between anthropometry (22, 29, 30, 43) and training (8, 29, 30, 41) in an Ironman race time. Regarding the anthropometric characteristics, in male Ironman triathletes, percent body fat (22, 29, 30) and the skin-fold thicknesses of the upper body (22) were related to an Ironman race time. Apart from anthropometry, training also influences race performance in Ironman triathletes. Training distances appear to be more important compared to training paces in Ironman race preparation (41) where weekly cycling distances but not cycling speed was associated with Ironman race time (8). In another study, however, speed in running during training was related to Ironman race time (33). Apart from training characteristics, both a personal best marathon time (33) and a personal best time in an Olympic distance triathlon (8, 33) were predictor variables for Ironman race time in recreational male Ironman triathletes. However, cycling performances seemed to be of particular importance in long-distance triathlons since in Ironman triathletes the physique was most similar to that of cyclists.

A comparison of height, weight, and percent body fat of Ironman triathletes with literature data of elite athletes from the sports disciplines of swimming, cycling and running showed that the physique of triathletes was most similar to that of cyclists (43). Furthermore, previous best performances in an Olympic distance triathlon coupled with weekly cycling distances and the longest training ride could partially predict overall Ironman race performance (8). This assumption was supported by recent findings in Triple Iron ultra-triathletes, where cycling performance was highly significantly related to total race time (14).

Since the physique of Ironman triathletes was considered to be similar to that of cyclists (43), we intended to investigate differences and similarities in both anthropometry and training between Ironman triathletes and ultra-endurance cyclists. Recent comparisons between Ironman triathletes and ultra-swimmers (13) and Triple Iron ultra-triathletes with ultra-runners (23) assumed that triathletes were not similar to swimmers and runners regarding anthropometric and training characteristics. O'Toole *et al*. (43) compared a rather small group of 14 triathletes (six females and eight males) to anthropometric literature data from cyclists. We, therefore, compared the anthropometry and training of 83 male Ironman triathletes competing in a qualifier for the Ironman World Championship in Hawaii to the anthropometry and training of 84 ultra-endurance cyclists competing in a qualifier for the 'Race Across America' (RAAM), the longest and most challenging ultra-endurance cycling race in the world.

The intention of this study was to find differences and similarities between Ironman triathletes and ultra-endurance cyclists. The first aim of this study was to investigate whether Ironman triathletes showed differences or similarities in anthropometric and training characteristics compared to ultra-endurance cyclists; the second aim was to investigate whether race performance was related to anthropometric characteristics, training characteristics or both in these ultra-endurance athletes.

We hypothesized that [1] anthropometric characteristics would be similar for both Ironman triathletes and ultra-endurance cyclists and [2] cycling volume in training would be related to an Ironman race time.

Materials and Methods

We collected data from Ironman triathletes in the 2009 'IRONMAN SWITZERLAND' race (http://www.ironman.ch/) and from ultra-cyclists in the 'Swiss Cycling Marathon' (http://www.radmarathon.ch/). In order to increase the sample size for the ultra-endurance cyclists, we collected data in three consecutive years from 2007 to 2009 since participation in ultra-endurance races is considerably low including a low finisher rate (18). Athletes in the 'IRONMAN SWITZERLAND' can qualify for the Ironman World Championship, the 'Ironman Hawaii'; athletes in the 'Swiss Cycling Marathon' can qualify for a 720 km (444 miles) cycling course in the 'RAAM'. In both races, the athletes were contacted three months before the race *via* a separate newsletter from the organiser upon inscription to the race and informed about the planned investigation. The subjects 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.

The Races

On July 12, 2009, 'IRONMAN SWITZERLAND' took place in the heart of the City of Zurich, Switzerland. A total of 2,203 male Ironman triathletes from 49 countries started at 07:00 a.m. At the start, the air temperature was 14°C and the water temperature in Lake Zurich was 20°C. Due to the low water temperature, wetsuits were allowed. At the start, the sky was clear but became cloudy gradually during the afternoon and evening. The highest temperature, 22°C, was reached in the afternoon. 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, followed by running four laps of 10.5 km each. In the cycling part, 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 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.

The 'Swiss Cycling Marathon' is an ultra-endurance cycling race, where athletes in the 720 km distance can be qualified for the 'RAAM'. The 'Swiss Cycling Marathon' takes place at the end of June/start of July. In the 720 km race, the 'RAAM'-qualifier, the participants must first complete a 600 km loop and then an additional loop of 120 km. In total, they pass 11 checkpoints offering nutrition and have to climb ~5,580 metres of altitude. The 600 km loop starts from the outskirts of Berne (Switzerland) leads over the border to Germany, then along Lake Constance into the Alps of Eastern Switzerland and back to Berne. Then, they must do the 120 km loop. Athletes who feel unable to complete the race can stop after 600 km. Athletes can be followed by a support car and/or rely on the nutrition provided by the organiser. Weather conditions were comparable in the three years.

The Subjects

All interested starters in both races were included when they officially finished the race. Athletes participating in both races were excluded. In the three editions of the 'Swiss Cycling Marathon', athletes were only included upon their first participation. In 'IRONMAN SWITZERLAND', a total of 98 non-professional male Ironman triathletes volunteered to take part in the investigation; 83 participants with 41.5 ± 8.9 years of age, 1.80 ± 0.07 m body height, 77.3 ± 8.9 kg body mass and a body mass index of 23.7 ± 2.1 kg/m^2 completed the race within the time limit of 16 h. Among the cyclists in the 'Swiss Cycling Marathon', a total of 90 non-professional ultra-endurance cyclists were interested in the investigation. Eighty-four cyclists with 43.8 ± 7.5 years of age, 1.80 ± 0.06 m of body height, 77.6 ± 8.4 kg of body mass and a body mass index of 23.8 ± 2.2 kg/m^2 finished the races within the time limit of 33 h.

Measurements and Calculations

Upon entering the study, the triathletes kept a comprehensive training diary recording their training sessions in swimming, cycling and running, including the distance (km), duration (h) and speed (km/h) for each training session and discipline until the start of the race. The cyclists also kept a training diary and recorded their training sessions in cycling showing the distance (km), duration (h) and speed (km/h) for each training session.

Before the start of each race body mass, body height, the lengths and the circumferences of the limbs and the thicknesses of skin-folds at eight sites (pectoral, axilla, triceps, subscapular, abdominal, iliacal, thigh, calf) were measured. Skin-fold thicknesses as well as lengths and circumferences of limbs were measured on the right side of the body. One trained investigator took all the anthropometric measurements as inter-tester variability is a major source of error in anthropometric measurements. With this data, we calculated body mass index 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 determined to the nearest 1.0 cm using a stadiometer. The circumferences and the lengths of the limbs were measured using a nonelastic tape measure (cm) (KaWe CE, Kirchner und Welhelm, Germany). The circumference of the upper arm was measured at mid-upper arm, the circumference of thigh at mid-thigh and the circumference of calf at mid-calf. The 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 and then the procedure was repeated twice more by the same investigator; the mean of the three times was then used for the analyses. The timing of the taking of the skin-fold measurements was standardised to ensure reliability. According to Becque *et al.* (3) readings were performed 4 s after applying the calliper. An intra-tester reliability check was conducted on 27 male athletes prior to testing (17). Intra-class correlation (ICC) within the two judges was excellent for all anatomical measurement sites, and various summary measurements of skin-fold thicknesses (ICC > 0.9). Agreement tended to be higher within measurers than between measurers but still reached excellent reliability (ICC > 0.9) for the summary measurements of the skin-fold thicknesses. Percent body fat was calculated using the anthropometric formula according to Ball *et al.* (2) with percent body fat = 0.465 +

Table 1. Comparison of anthropometry and training between Ironman triathletes and ultra-cyclists

	Ironman triathletes (n = 83)	Ultra-cyclists (n = 84)
Age (years)	41.5 ± 8.9	43.8 ± 7.5
Body mass (kg)	77.3 ± 8.9	77.6 ± 8.4
Body height (m)	1.80 ± 0.07	1.80 ± 0.06
Body mass index (kg/m^2)	23.7 ± 2.1	23.8 ± 2.2
Length leg (cm)	86.4 ± 5.0*	88.4 ± 4.4
Length arm (cm)	81.5 ± 4.0	81.2 ± 4.1
Circumference upper arm (cm)	27.0 ± 2.6*	30.4 ± 2.1
Circumference thigh (cm)	54.2 ± 2.9**	56.5 ± 3.1
Circumference calf (cm)	37.2 ± 2.3*	38.2 ± 2.1
Skin-fold thickness pectoral (mm)	7.0 ± 4.0	7.0 ± 3.3
Skin-fold thickness axilla (mm)	9.2 ± 4.5	8.5 ± 3.3
Skin-fold thickness triceps (mm)	7.9 ± 4.5	7.4 ± 3.2
Skin-fold thickness subscapular (mm)	10.3 ± 4.1	10.4 ± 4.4
Skin-fold thickness abdominal (mm)	16.0 ± 8.8	16.1 ± 8.4
Skin-fold thickness iliacal (mm)	16.4 ± 8.7	16.0 ± 7.0
Skin-fold thickness thigh (mm)	12.2 ± 5.8	12.3 ± 5.8
Skin-fold thickness calf (mm)	7.4 ± 3.1	5.5 ± 2.9
Skeletal muscle mass (kg)	38.6 ± 4.2*	40.3 ± 3.5
Percent body fat (%)	15.7 ± 4.6	15.7 ± 4.3
Training volume in hours per week	14.1 ± 5.7*	12.7 ± 6.4
Hours of cycling per week in training	7.0 ± 2.3**	12.6 ± 6.3
Kilometres of cycling per week in training	189.5 ± 70.2**	354.5 ± 181.8
Speed in cycling during training (km/h)	28.1 ± 2.9	27.5 ± 3.1
Hours of swimming per week in training	2.5 ± 1.2	
Kilometres of swimming per week in training	6.0 ± 2.9	
Speed in swimming during training (km/h)	2.8 ± 0.6	
Hours of running per week in training	4.7 ± 4.3	
Kilometres of running per week in training	44.8 ± 17.6	
Speed in running training (km/h)	11.2 ± 1.2	

Results are presented as means ± SD. *: $P < 0.05$, **: $P < 0.01$.

0.180 × (Σ7SF) - 0.0002406 × (Σ7SF)^2 + 0.0661 × (age), where Σ7SF = sum of skin-fold thickness of pectoralis, axilla, triceps, subscapular, abdomen, suprailiac and thigh mean. Skeletal muscle mass (SMM) was estimated using the formula of Lee *et al.* (35) with SMM = Ht × (0.00744 × CAG^2 + 0.00088 × CTG^2 + 0.00441 × CCG^2) + 2.4 × sex − 0.048 × 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; age is in years; race = 0 for white men and 1 for black men.

Statistical Analyses

The Shapiro-Wilk test was used to check for normal distribution. Normally distributed data are presented as means ± standard deviation (SD). Variables of anthropometry and training between ultra-cyclists and Ironman triathletes were compared using the Wilcoxon signed rank test. The directly measured anthropometric characteristics body mass, body height, skin-fold thicknesses, lengths and circumferences of limbs and the calculated anthropometric characteristics body mass index, skeletal muscle mass, the sum of eight skin-folds and percent body fat were related to total race time including split times for Ironman triathletes using Pearson correlation analysis. Race time was also expressed as a percentage of the course record (8:12 h:min for the Ironman distance and 22:24 h:min for the 720 km cycling distance). A power calculation was performed according to Gatsonis and Sampson (7). To achieve a power of 80% (two-sided Type I error of 5%) to detect a minimal association between race time and anthropometric characteristics of 20% (*i.e.* coefficient of determination $r^2 = 0.2$) a sample of 40 participants was required. To investigate an effect between the investigated variables with race time, the effect size of Pearson's correlation was applied. A small effect size is given as † in the tables for $r = 0.1 - 0.23$, # = a medium effect size for $r = 0.24 - 0.36$ and § = a large effect size for

Table 2. Association of anthropometric and training characteristics with overall race time

	Ironman triathletes (n = 83)				Ultra-cyclists (n = 84)
	Total race time	Split time for swimming	Split time for cycling	Split time for running	Race time
Age	0.35, $P = 0.0011^{\#}$	0.39, $P = 0.0003^{\S}$	0.33, $P = 0.0025^{\#}$	0.22, $P = 0.0474^{\dagger}$	0.31, $P = 0.0042^{\#}$
Body height	0.02	-0.03	-0.11	0.13	0.07
Body mass	0.34, $P = 0.0017^{\#}$	0.17	0.16	0.46, $P < 0.0001^{\S}$	0.09
Body mass index	0.42, $P < 0.0001^{\S}$	0.24, $P = 0.0301^{\#}$	0.30, $P = 0.0063^{\#}$	0.48, $P < 0.0001^{\S}$	0.17
Length leg	-0.08	-0.13	-0.15	0.02	-0.04
Length arm	0.13	0.03	0.02	0.20	0.03
Circumference upper arm	0.40, $P = 0.0002^{\S}$	0.18	0.30, $P = 0.0059^{\#}$	0.47, $P < 0.0001^{\S}$	0.04
Circumference thigh	0.28, $P = 0.0096^{\#}$	0.14	0.17	0.37, $P = 0.0005^{\S}$	-0.14
Circumference calf	0.23, $P = 0.0388^{\dagger}$	0.02	0.12	0.34, $P = 0.0015^{\#}$	-0.09
Skin-fold thickness pectoral	0.41, $P = 0.0001^{\S}$	0.33, $P = 0.0020^{\#}$	0.41, $P = 0.0001^{\S}$	0.27, $P = 0.0123^{\#}$	0.45, $P < 0.0001^{\S}$
Skin-fold thickness axilla	0.42, $P < 0.0001^{\S}$	0.34, $P = 0.0016^{\#}$	0.36, $P = 0.0008^{\#}$	0.34, $P = 0.0017^{\#}$	0.39, $P = 0.0002^{\S}$
Skin-fold thickness triceps	0.29, $P = 0.0079^{\#}$	0.13	0.27, $P = 0.0150^{\#}$	0.24, $P = 0.0289^{\#}$	0.25, $P = 0.0203^{\#}$
Skin-fold thickness subscapular	0.54, $P < 0.0001^{\S}$	0.48, $P < 0.0001^{\S}$	0.50, $P < 0.0001^{\S}$	0.40, $P = 0.0002^{\S}$	0.35, $P = 0.0011^{\#}$
Skin-fold thickness abdominal	0.43, $P < 0.0001^{\S}$	0.40, $P = 0.0002^{\S}$	0.39, $P = 0.0003^{\S}$	0.31, $P = 0.0038^{\#}$	0.38, $P = 0.0004^{\S}$
Skin-fold thickness iliacal	0.36, $P = 0.0008^{\#}$	0.26, $P = 0.0159^{\#}$	0.34, $P = 0.0017^{\#}$	0.26, $P = 0.0189^{\#}$	0.32, $P = 0.0033^{\#}$
Skin-fold thickness thigh	0.26, $P = 0.0173^{\#}$	0.06	0.25, $P = 0.0201^{\#}$	0.22, $P = 0.0418^{\dagger}$	0.23, $P = 0.0367^{\dagger}$
Skin-fold thickness calf	0.00	-0.24, $P = 0.0257^{\#}$	0.00	0.08	0.25, $P = 0.0230^{\#}$
Skeletal muscle mass	0.17	0.04	0.03	0.31, $P = 0.0039^{\#}$	-0.18
Percent body fat	0.48, $P < 0.0001^{\S}$	0.39, P = $0.0003^{\S}$	0.45, $P < 0.0001^{\S}$	0.35, $P = 0.0013^{\#}$	0.42, $P < 0.0001^{\S}$
Weekly training hours	-0.05	-0.10	-0.09	0.05	-0.22, $P = 0.0479^{\dagger}$
Hours of discipline-specific training	-	-0.23, $P = 0.0382^{\dagger}$	0.02	0.02	-0.22, $P = 0.0479^{\dagger}$
Kilometres of discipline-specific training	-	-0.36, $P = 0.0010^{\#}$	-0.06	-0.16	-0.20
Speed in discipline-specific training	-	-0.28, $P = 0.0094^{\#}$	-0.28, $P = 0.0109^{\#}$	-0.27, $P = 0.0146^{\#}$	-0.13

For the Ironman triathletes, the association with the time for the cycling split is also inserted. R-values show effect size. *P*-value is presented in case of a significant association. A small effect size is given as † for $r = 0.1 – 0.23$, # = a medium effect size for $r = 0.24 – 0.36$ and § = a large effect size for $r = 0.37$ or larger following Cohen (5, 6).

$r = 0.37$ or larger following Cohen (5, 6). Statistical analysis was performed using 'Analyse-it Software' (City West Business Park, 3 The Boulevard, Leeds, LS12 6LX, United Kingdom). To investigate predictor variables for overall race time, a multiple linear regression analysis was assessed with race time as the dependent variable separately for Ironman triathletes and ultra-cyclists. Statistical significance was set at $P < 0.05$.

Results

The Ironman triathletes completed the 3.8 km swimming, 180 km cycling and 42.195 km running within 11:15 h:min, 689 ± 79 min, respectively. Expressed as a percentage of the course record, the athletes finished after 139 ± 15% of the course record. The ultra-cyclists completed the 720 km within 28:06 h:min, 1,686 ± 255 min, respectively. This finish time was equal to 125 ± 19% of the course record. Race time, expressed as a percentage of the course record, was significantly less for the ultra-cyclists compared to the Ironman triathletes ($P < 0.001$).

The Ironman triathletes had shorter legs, lower circumferences of upper arm, thigh and calf and a lower skeletal muscle mass compared to the ultra-cyclists (see Table 1). Regarding training, the Ironman triathletes invested more weekly training hours but fewer cycling hours than the ultra-cyclists. However, the ultra-cyclists completed more cycling kilometres per week. Table 2 shows the bi-variate analysis of both the anthropometric and training characteristics with total race time for both the Ironman triathletes and the ultra-cyclists. In addition, the anthropometric and training characteristics were also related to the split times for the Ironman triathletes. For the Ironman triathletes, a large effect size ($r > 0.37$) for total race time was found for body mass index, the circumference of the upper arm, the skin-fold thicknesses at pectoral, axillar, subscapular and abdominal site as well as for percent body fat. In the ultra-cyclists, a large effect size for race time was found for the skin-fold thicknesses at pectoral, axillar, and abdominal site as well as for percent body fat. For the Ironman triathletes, in the multi-variate analysis for anthropometric and training characteristics with total race time, the skin-fold thickness at abdominal and iliacal site as well as percent body fat were associated with overall race time (see Table 3). When all significant variables after bi-variate analysis for the cycling split time were inserted in a multi-variate analysis, abdominal and iliacal skin-fold thicknesses, percent body fat and

Table 3. Multiple linear regression analysis with race time as the dependent variable for Ironman triathletes (n = 83)

Ironman triathletes	β	SE	*P*-value
Body mass	-0.56	1.60	0.72
Body mass index	4.67	7.00	0.50
Circumference of upper arm	3.85	5.43	0.48
Circumference of thigh	-1.43	4.93	0.77
Circumference of calf	6.78	4.94	0.17
Skin-fold thickness pectoral	-2.51	3.92	0.52
Skin-fold thickness axilla	-3.28	-0.94	0.34
Skin-fold thickness triceps	-5.71	5.10	0.26
Skin-fold thickness subscapular	4.64	3.50	0.18
Skin-fold thickness abdominal	-6.03	2.53	0.02
Skin-fold thickness iliacal	-4.76	2.05	0.02
Skin-fold thickness thigh	-4.33	2.24	0.05
Percent body fat	33.91	9.68	0.0008

β = regression coefficient; SE = standard error of the regression coefficient; Coefficient of determination (r^2) of the model was 46%.

Table 4. Multiple linear regression analysis with split time in cycling as the dependent variable for Ironman triathletes (n = 83)

Ironman triathletes	β	SE	*P*-value
Body mass index	0.58	2.87	0.84
Circumference of upper arm	1.43	2.34	0.54
Skin-fold thickness pectoral	0.65	1.78	0.71
Skin-fold thickness axilla	-2.48	1.63	0.13
Skin-fold thickness triceps	-3.48	2.40	0.15
Skin-fold thickness subscapular	2.97	1.66	0.07
Skin-fold thickness abdominal	-3.74	1.20	0.003
Skin-fold thickness iliacal	-2.35	0.98	0.02
Skin-fold thickness thigh	-1.27	1.08	0.24
Percent body fat	16.05	4.66	0.001
Speed in cycling during training	-3.01	1.19	0.01

β = regression coefficient; SE = standard error of the regression coefficient; Coefficient of determination (r^2) of the model was 44%.

Table 5. Multiple linear regression analysis with race time as the dependent variable for ultra-cyclists (n = 84)

Ultra-cyclists	β	SE	*P*-value
Skin-fold thickness pectoral	22.47	16.76	0.18
Skin-fold thickness axilla	-16.49	22.83	0.47
Skin-fold thickness triceps	-33.83	16.13	0.39
Skin-fold thickness subscapular	-14.24	14.43	0.32
Skin-fold thickness abdominal	-10.82	9.04	0.23
Skin-fold thickness iliacal	-15.87	9.26	0.09
Skin-fold thickness thigh	-6.78	9.38	0.47
Skin-fold thickness calf	-6.32	13.80	0.64
Percent body fat	103.8	51.3	0.04
Weekly cycling hours	-9.96	4.33	0.11

β = regression coefficient; SE = standard error of the regression coefficient; Coefficient of determination (r^2) of the model was 29%.

Table 6. Relationship of anthropometric characteristics with training variables for the Ironman triathletes (n = 83)

	Weekly training hours	Weekly cycling hours	Weekly cycling kilometres	Speed in cycling during training	Weekly swimming hours	Weekly swimming kilometres	Speed in swimming during training	Weekly running hours	Weekly running kilometres	Speed in running during training
Circumference upper arm	-0.02	0.12	0.16	-0.08	-0.06	0.07	-0.14	-0.09	-0.10	-0.33, $P = 0.0027$
Circumference thigh	0.07	0.13	0.19	0.13	-0.05	0.06	-0.21	0.03	0.03	-0.18
Circumference calf	0.06	0.16	0.20	0.07	-0.09	-0.03	-0.16	0.03	0.02	-0.25, $P = 0.0025$
Skin-fold thickness pectoral	-0.21	-0.16	-0.20	-0.09	-0.06	-0.12	-0.10	-0.17	-0.20	-0.12
Skin-fold thickness axilla	-0.12	-0.16	-0.19	0.00	-0.07	-0.10	-0.11	-0.06	-0.14	0.04
Skin-fold thickness triceps	-0.04	-0.13	-0.07	0.09	0.03	0.03	0.02	0.01	0.01	0.05
Skin-fold thickness subscapular	-0.01	-0.02	-0.07	-0.03	0.03	0.00	-0.09	-0.01	-0.04	-0.04
Skin-fold thickness abdominal	-0.09	-0.10	-0.15	-0.12	0.00	-0.05	-0.16	-0.06	-0.14	-0.08
Skin-fold thickness iliacal	-0.14	-0.15	-0.18	-0.05	-0.04	-0.05	-0.01	-0.09	-0.15	-0.03
Skin-fold thickness thigh	-0.04	-0.08	0.01	0.12	-0.04	0.03	0.10	-0.08	-0.11	-0.18
Skin-fold thickness calf	-0.06	0.09	0.09	0.03	0.10	0.22	0.13	-0.14	-0.12	-0.02
Percent body fat	-0.10	-0.15	-0.16	-0.05	-0.05	-0.07	-0.09	-0.06	-0.14	-0.07
Skeletal muscle mass	0.05	0.17	0.18	0.05	-0.07	0.00	-0.12	0.04	0.01	-0.24, $P = 0.0269$

P-value is inserted in case of a significant association. Significance was set as $P < 0.05$.

Table 7. Relationship of anthropometric characteristics with training variables for the ultra-cyclists (n = 84)

	Weekly training hours	Weekly cycling kilometres	Speed in cycling during training
Circumference upper arm	-0.01	0.02	0.08
Circumference thigh	-0.10	-0.09	0.19
Circumference calf	-0.03	-0.12	0.02
Skin-fold thickness pectoral	-0.19	-0.24, $P = 0.0252$	-0.04
Skin-fold thickness axilla	-0.23, $P = 0.0318$	-0.24, $P = 0.0309$	-0.07
Skin-fold thickness triceps	-0.10	-0.22, $P = 0.0400$	-0.03
Skin-fold thickness subscapular	-0.11	-0.14	-0.02
Skin-fold thickness abdominal	-0.20	-0.24, $P = 0.0302$	-0.14
Skin-fold thickness iliacal	-0.24, $P = 0.0248$	-0.29, $P = 0.0068$	-0.16
Skin-fold thickness thigh	0.04	-0.04	-0.13
Skin-fold thickness calf	-0.05	-0.11	-0.04
Percent body fat	-0.16	-0.22, $P = 0.0421$	-0.14
Skeletal muscle mass	0.04	0.11	0.28, $P = 0.0095$

P-value is inserted in case of a significant association. Significance was set as $P < 0.05$.

cycling speed during training were related to cycling split time in the Ironman race (see Table 4). For the ultra-cyclists, percent body fat was related to race time (see Table 5).

When a potential association between the anthropometric and the training characteristics was investigated using correlation analysis for the Ironman triathletes (see Table 6), the speed in running during training was significantly and negatively associated with the circumference of upper arm and calf as well as with skeletal muscle mass (see Fig. 1). For the ultra-endurance cyclists, the skin-fold thicknesses at both axilla and iliacal site were significantly and negatively associated with both weekly cycling hours and kilometres; those at pectoral, triceps and abdominal site as well as percent body fat were significantly and negatively related to the weekly cycling kilometres (see Table 7). The skeletal muscle mass was significantly and positively associated with the speed in cycling during training (see Fig. 2).

Discussion

The first aim of this study was to investigate whether Ironman triathletes showed differences or similarities in anthropometric and training characteristics compared to ultra-endurance cyclists. The main findings were that the Ironman triathletes had shorter legs, lower limb circumferences and a lower skeletal muscle mass compared to the ultra-endurance cyclists. The difference in leg length seemed to have no disadvantage for the triathletes. The leg length

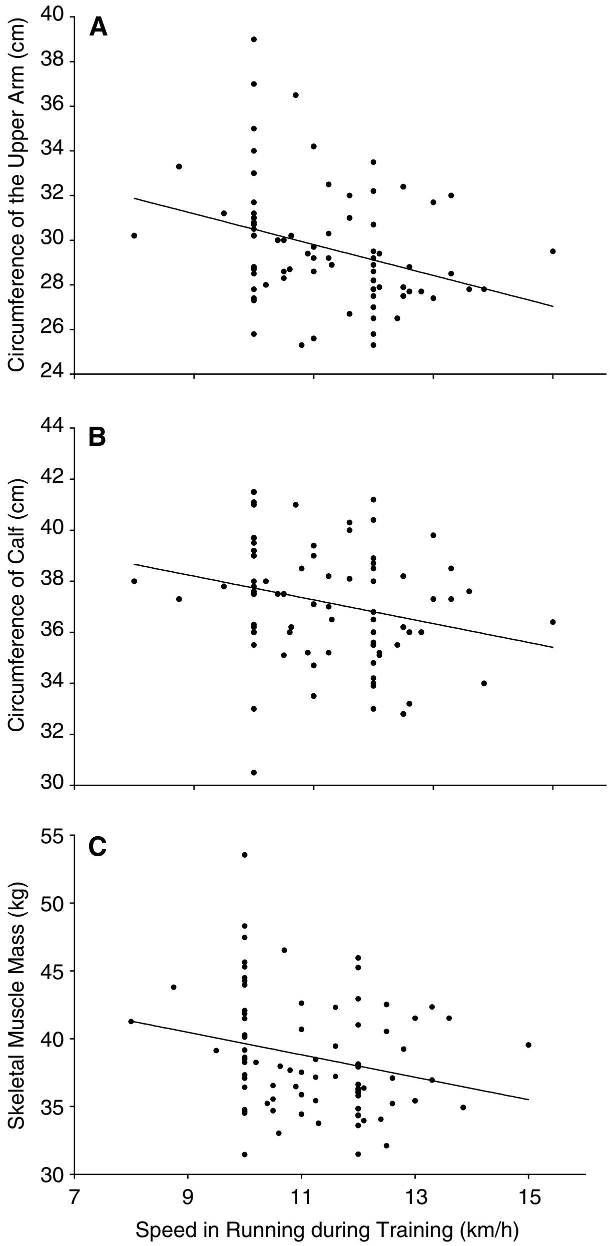

Fig. 1. For the Ironman triathletes (n = 83), speed in running during training was significantly and negatively related to the circumference of upper arm (r = -0.33, P = 0.0027) (Panel A), to the circumference of calf (r = -0.25, P = 0.0225) (Panel B) and to skeletal muscle mass (r = -0.24, P = 0.0269) (Panel C).

showed neither for the Ironman triathletes nor for the ultra-cyclists an association with total race time in the bi-variate analysis. The circumference of the limbs as well as body mass were positively related to both total race time and split time in running for the Ironman triathletes, but not to total race time for the ultra-endurance cyclists. The circumferences of both upper arm and calf were significantly and negatively related to the running speed during training. Two

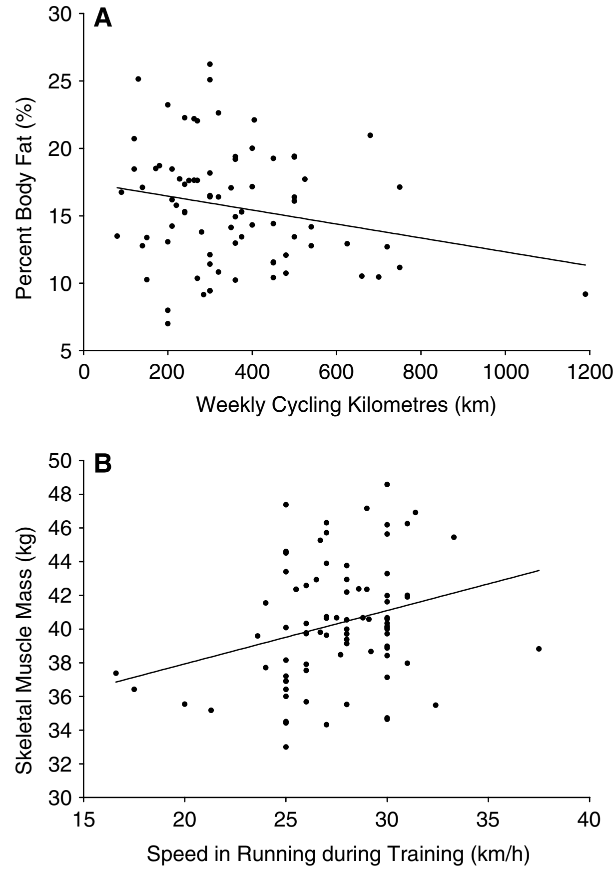

Fig. 2. For the ultra-endurance cyclists (n = 84), percent body fat was significantly and negatively related to weekly cycling kilometres (r = -0.22, P = 0.0421) (Panel A); skeletal muscle mass was significantly and positively associated with speed in cycling during training (r = 0.28, P = 0.0095) (Panel B).

studies on ultra-runners showed that the upper arm circumference was significantly and negatively related to an ultra-marathon performance (15, 25). Since correlation analysis cannot prove cause and effect, it is difficult to interpret these findings that lower limb circumferences are associated with faster race performances. One might argue that lower limb circumferences enhance fast running. However, low limb circumferences might also be due to genetics or diet. The skeletal muscle mass was also related to the split time in running but neither to the split time in swimming nor in cycling. A main difference between running to swimming and cycling is the change from a non-weight-bearing to a weight-bearing activity (4, 9); so low body mass may enhance faster running.

The second aim was to study whether race performance was related to anthropometric characteristics, training characteristics or both. Percent body fat was related to total race time for both Ironman triathletes and ultra-cyclists. In the multi-variate analysis, when corrected for all covariates, percent body fat was related to race time for both the ultra-cyclists and the Ironman triathletes. This corresponds well with recent findings in short distance triathletes (34, 45), Ironman triathletes (22, 29, 30), Triple Iron ultra-triathletes (21) and ultra-endurance cyclists (32) where body fat was related to race performance times. In addition, body mass was also related to total race time in Ironman triathletes after bi-variate analysis. In the literature, there were no references regarding an association between body mass and race performance for Ironman triathletes. However, there are studies showing that both body mass (50) and body fat (32) were related to performance in cyclists. When the split time in cycling was the dependent variable in a separate regression model, percent body fat and both the iliacal and abdominal skin-fold thicknesses remained anthropometric predictor variables while body mass was eliminated. These findings show that low body fat is important for both a fast split time in cycling and total race time for triathletes (21, 22, 29, 30, 34, 45).

We may ask now whether the skin-fold thicknesses and body fat were related to training. In recent studies, an association between the thicknesses of selected skin-folds of the upper and lower body and running performance has been demonstrated in top-class male and female runners who ran distances from 100 m to 10,000 m and the marathon, respectively (1, 36). High correlations were described for male runners between both the front thigh and the medial calf skin-fold thickness and 10,000-m race times (1). It was supposed that the thickness of skin-folds at the lower limb was a result of intense training in running (36). For both the Ironman triathletes and the ultra-cyclists, all skin-fold thicknesses of the upper body were related to race time as has already recently been described for Ironman triathletes (22). The thigh skin-fold thickness was associated with total Ironman race time and both the split time in cycling and running as well as the total race time in the ultra-cyclists. The calf skin-fold thickness, however, was related to the split time in swimming and in the ultra-cyclists to overall race time. This finding is in contrast to Arrese and Ostáriz (1) who described a significant and positive association of both thigh and calf skin-fold thickness with running times over 10,000 m in high-level runners. Skin-fold thicknesses seem not to be a reliable predictor variable for ultra-endurance performance. The finding that calf skin-fold thickness is related to running performance could be reproduced only in one study investigating ultra-marathoners (27). For other ultra-endurance athletes such as ultra-cyclists (20, 28), however, skin-fold thicknesses of the lower limbs were not related to an ultra-endurance performance.

Legaz and Eston (36) assumed that intense training leads to a reduction in adipose tissue and therefore to reduced skin-fold thicknesses of the lower limbs. In these Ironman triathletes, no association could be described between skin-fold thicknesses and body fat with training characteristics. In the ultra-cyclists, however, selected skin-fold thicknesses of the upper body were significantly and negatively related to both weekly cycling hours and weekly cycling kilometres. Presumably, long cycling sessions may reduce adipose subcutaneous tissue. This might be in line with previous findings when an ultra-cycling race over 600 km led to a reduction of subcutaneous adipose tissue (31). In the ultra-cyclists, the skeletal muscle mass was significantly and positively related to the speed in cycling during training. One might assume that athletes training fast may increase their skeletal muscle mass. However, the skeletal muscle mass was not associated with the overall race time in contrast to body fat. Also, body fat was significantly and negatively related to weekly cycling kilometres. Since body fat was the single predictor variable for the overall race time in the ultra-cyclists, low body fat might be of higher importance for a fast cycling time in an ultra-endurance cycling race (32) than increased skeletal muscle mass.

Regarding training, the Ironman triathletes invested more total hours in training compared to ultra-cyclists, but fewer hours and kilometres regarding cycling training. The weekly training hours were related to overall race time in the ultra-cyclists, but not in the Ironman triathletes. This might be due to the fact that triathletes have to train not only for cycling but also for the two other disciplines swimming and running. The speed in cycling during training was related to the split time in cycling for the Ironman triathletes, but not for the total Ironman race time or the race time in the ultra-cyclists. The Ironman triathletes invested significantly more training hours compared to ultra-cyclists. However, the ultra-cyclists invested highly significantly more training hours and cycling kilometres compared to the Ironman triathletes. The Ironman triathletes must train and race in three different disciplines. Therefore, they also have to invest time in swimming and running training. The finding, that speed in cycling training was related to overall race time in Ironman triathletes, is different from previously reported findings. O'Toole (42) concluded that distance appeared to be more important than pace in training, especially for cycling. Gulbin and Gaffney (8) demonstrated that both the weekly cycling distances and the longest training rides were associated with Ironman performance times. Hendy and Boyer (10), however, found no clear pattern regarding training and performance in cycling.

To date, Ironman triathletes showed no similarities in anthropometry and training with ultra-swimmers (13) and ultra-cyclists as found in the present investigation. The negative findings in the actual study might also be due to the sample of these recreational Ironman triathletes. Their race time, expressed in percentage of the course record, was ~15% slower compared to the performance of the ultra-endurance cyclists. Elite Ironman triathletes would probably have produced different results. In future studies, Ironman triathletes should be compared with marathoners, since personal best marathon time was a predictor variable for Ironman race time (31) although a recent study found no similarities between ultra-triathletes and ultra-runners (31). However, for Triple Iron ultra-triathletes, total race time was associated with performance in cycling and running (14, 26).

This study was limited as nutritional intake was not assessed. It is very likely that race nutrition will influence overall race time in Ironman events (12). The problem of fluid intake and, especially, exercise-associated hyponatremia might have an influence on race time (46, 47). In further studies, nutrition should also be considered. Furthermore, the determination of physiological characteristics such as maximum oxygen uptake or lactate threshold would be useful (42). Apart from variables of physiology, anthropometry, training and previous experience, the aspect of motivation might also considerably influence Ironman race outcome (44, 48). A further limitation is that we have not respected environmental conditions; environmental factors might influence race performance (51).

To summarize, the Ironman triathletes had shorter legs, lower circumferences of upper arm, thigh and calf and a lower skeletal muscle mass compared to the ultra-cyclists. In addition, the Ironman triathletes invested more weekly training hours but less cycling hours than the ultra-cyclists; the ultra-cyclists completed more cycling kilometres per week. We concluded that anthropometry of Ironman triathletes was not similar to anthropometry of ultra-endurance cyclists. In future studies, Ironman triathletes should be compared with marathoners regarding anthropometry and training.

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