Journal of Sports Sciences
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/rjsp20

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Available online: 11 Aug 2011

Journal of Sports Sciences, 2011; 1–8, i*First* article

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A comparison of anthropometric and training characteristics of Ironman triathletes and Triple Iron ultra-triathletes

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(Accepted 9 May 2011)

Abstract

We examined differences in anthropometry and training between 64 Triple Iron ultra-triathletes competing over 11.4 km swimming, 540 km cycling, and 126.6 km running, and 71 Ironman triathletes competing over 3.8 km swimming, 180 km cycling, and 42.2 km running. The association of anthropometry and training with race time was investigated using multiple linear regression analysis. The Triple Iron ultra-triathletes were smaller ($P < 0.05$), had shorter limbs ($P < 0.05$), a higher body mass index ($P < 0.05$), and larger limb circumferences ($P < 0.01$) than the Ironman triathletes. The Triple Iron ultra-triathletes trained for more hours ($P < 0.01$) and covered more kilometres ($P < 0.01$), but speed in running during training was slower compared with the Ironman triathletes ($P < 0.01$). For Triple Iron ultra-triathletes, percent body fat ($P = 0.022$), training volume per week ($P < 0.0001$), and weekly kilometres in both cycling ($P < 0.0001$) and running ($P < 0.0001$) were related to race time. For Ironman triathletes, percent body fat ($P < 0.0001$), circumference of upper arm ($P = 0.006$), and speed in cycling training ($P = 0.012$) were associated with total race time. We conclude that both Triple Iron ultra-triathletes and Ironman triathletes appeared to profit from low body fat. Triple Iron ultra-triathletes relied more on training volume in cycling and running, whereas speed in cycling training was related to race time in Ironman triathletes.

Keywords: *Ultra-endurance, body fat, skinfolds, body composition*

Introduction

The sports discipline of 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 (Sultana, Brisswalter, Lepers, Hausswirth, & Bernard, 2008), the Ironman distance of 3.8 km swimming, 180 km cycling, and 42.2 km running (Lepers, 2008; Lepers & Maffiuletti, 2011; Lepers, Sultana, Thierry, Hausswirth, & Brisswalter, 2010; Neubauer, König, & Wagner, 2008), and longer distances such as the Triple Iron ultra-triathlon over 11.4 km swimming, 540 km cycling, and 126.6 km running (Knechtle, Duff, Amtmann, & Kohler, 2007a; Knechtle & Kohler, 2009).

The Ironman distance is the most popular long-distance triathlon. Since the first edition in 1978, each year tens of thousands of triathletes have competed in Ironman races in order to qualify for the Ironman Hawaii. Every year, more than 1700 triathletes start in the World Championship in Hawaii (Lepers, 2008; Lepers & Maffiuletti, 2011). Competing and finishing an Ironman triathlon needs training and racing in three different disciplines where, apart from physiological variables, different variables of anthropometry might be associated with performance. Although the Ironman distance is the most famous long-distance triathlon, there are limited data regarding the association between anthropometry and race performance (Knechtle, Wirth, Baumann, Knechtle, & Rosemann, 2010c; Knechtle et al., 2010d; Knechtle, Knechtle, & Rosemann, & Senn, 2011a; O'Toole, Hiller, Crosby, & Douglas, 1987). For male Ironman triathletes, percent body fat was significantly and positively correlated to race time (Knechtle et al., 2010c, 2010d, 2011a).

Training appears also to influence race performance in Ironman triathletes (Gulbin & Gaffney,

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ISSN 0264-0414 print/ISSN 1466-447X online © 2011 Taylor & Francis
DOI: 10.1080/02640414.2011.587442

1999; O'Toole 1989). One study investigated the anthropometry in Ironman triathletes (O'Toole et al., 1987); two other studies investigated their training in race preparation (Gulbin & Gaffney, 1999; O'Toole 1989). Cycling performance appeared to be of particular importance in long-distance triathlons, since the physique of Ironman triathletes was most similar to that of cyclists (O'Toole et al., 1987). Training distances, however, seem to be more important than training paces in race preparation (O'Toole, 1989) for Ironman triathletes where weekly cycling distances were associated with race time (Gulbin & Gaffney, 1999). In general, however, intense training is often a performance-determining factor (Mujika, 2010).

Regarding the Triple Iron ultra-triathlon, where only $\sim$50 ultra-triathletes start per race (Knechtle, Knechtle, & Lepers, 2010a), studies have addressed the potential relationship between anthropometry and race performance (Knechtle et al., 2007a; Knechtle, Duff, Amtmann, & Kohler, 2008a; Knechtle, Knechtle, & Rosemann, 2009b; Knechtle & Kohler, 2009; Knechtle, Schwanke, Knechtle, & Kohler, 2008b). The sum of eight skinfold thicknesses (Knechtle et al., 2009b) and the sum of upper body skinfolds (Knechtle, Knechtle, Rosemann, & Senn, 2011b) were related to total race time. However, no relationship between training and race performance was found for Triple Iron ultra-triathletes (Knechtle et al., 2009b, 2011b).

To date, no study has compared Ironman triathletes and Triple Iron ultra-triathletes in terms of the relationships of anthropometric and training characteristics to race performance. The first aim of the present study was to investigate differences and similarities in anthropometry and training between Ironman triathletes and Triple Iron ultra-triathletes, and whether anthropometric and training variables are similarly related to race performance in the two groups of athletes. Although the Triple Iron distance is considerably longer than the Ironman distance, we assume that parallels do exist. A second aim was to determine whether anthropometric characteristics such as body fat and skinfold thicknesses are related to race time in both Ironman triathletes and Triple Iron ultra-triathletes. A third aim was to investigate potential associations between anthropometric and training characteristics.

Materials and methods

We collected data from Ironman triathletes in the 2009 Ironman SWITZERLAND race. Since participants in Triple Iron ultra-triathlons are few, we twice collected data from the Triple Iron Triathlon Germany, held over the same course in Lensahn, Schleswig-Holstein, Germany, in two consecutive years (2007 and 2008) to increase the sample size. In both races, the athletes were contacted via a separate newsletter from the organizer 3 months before the start of the race and informed about the planned investigation. The participants were informed of the experimental procedures and gave their informed written consent prior to the investigation. The investigation was approved by the Ethics Committee of St. Gallen, Switzerland.

Races

On 12 July 2009, Ironman SWITZERLAND took place in the heart of the City of Zurich, Switzerland. A total of 2534 male Ironman triathletes from 49 countries started the race at 07:00 h. At the start, the air temperature was 14°C and the temperature of the water in Lake Zurich was 20°C. Due to the low water temperature, wetsuits were allowed. The highest temperature, 22°C, was reached in the afternoon. The athletes had to swim two laps 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 section, the highest point to climb from Zurich (400 m above sea level) was the "Forch" (700 m above sea level), while the running course was completely flat in the City of Zurich.

From 27 to 29 July 2007 and 25 to 27 July 2008, the Triple Iron Triathlon Germany was held in Lensahn, Schleswig-Holstein, Germany, covering 11.6 km swimming, 540 km cycling, and 126.6 km running. The swim was held in a 50-m heated outdoor pool with a temperature of 25°C and wetsuits were allowed following IUTA (International Ultra-Triathlon Association) rules. After passing through the transition area, 67 laps of a hilly course of 8 km per lap had to be cycled in the surroundings of the town. After the cycling section, the athletes had to change to the flat running course of 96 laps of 1.31 km per lap in the town of Lensahn. The athletes had to arrive at the finish line within 58 h. They were free to stop for food and sleep during the race following IUTA rules. The general weather conditions were fine and comparable in both races.

Participants

In the 2009 Ironman SWITZERLAND, 2534 male Ironman triathletes from 49 countries started the event. In total, 98 non-professional male Ironman triathletes volunteered to take part in the investigation of whom 71 (mean age 41.7 years, $s = 9.2$; height of 1.81 m, $s = 0.06$; body mass 77.5 kg, $s = 8.9$; body mass index 23.7 $kg \cdot m^{-2}$, $s = 2.2$) completed the race within the time limit. In the Triple Iron

Triathlon Germany, a total of 88 male athletes started in the two races, 74 of whom participated in the investigation. The athletes racing in both years were included for one year only, the year of the study. A total of 64 non-professional male ultra-triathletes (mean age 39.8 years, $s = 8.3$; height 1.78 m, $s = 0.06$; body mass 77.8 kg, $s = 8.2$; body mass index of 24.5 $\text{kg} \cdot \text{m}^{-2}$, $s = 2.1$) finished the races within the time limit. No participant competed in both races.

Measurements and calculations

Upon entering the study, the athletes kept a comprehensive training diary recording their training units in swimming, cycling, and running, together with the distance (km), duration (h), and speed ($\text{km} \cdot \text{h}^{-1}$) for each training session and discipline until the start of the race. The evening before the start of the race, body mass, height, the length of arm and leg, the circumferences of limbs, and the thicknesses of skinfolds at eight sites (pectoralis, axillar, triceps, subscapular, abdomen, suprailiac, front thigh, and medial calf) were measured on the right side of the body. One trained investigator took all the measurements, as inter-tester variability is a major source of error in anthropometric measurements. With these data, we calculated body mass index, percent body fat, and the sum of eight skinfold thicknesses.

Body mass was measured using a commercial scale (Beurer BF 15, Beurer, Ulm, Germany) to the nearest 0.1 kg. Height was measured using a stadiometer to the nearest 1.0 cm. The circumferences and the lengths of the limbs were measured (cm) using a non-elasticated tape measure (KaWe CE, Kirchner und Welhelm, Germany). The length of the arm was measured from acromion to the tip of the third finger to the nearest 0.1 cm on the right side; the length of the leg from trochanter major to the middle of 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) in an anatomical position to the nearest 0.1 cm; the circumference of the thigh was taken at the level where the skinfold thickness of the 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. The skinfold data were obtained using a skinfold calliper (GPM-Hautfaltenmessgerät, Siber & Hegner, Zurich, Switzerland) and recorded to the nearest 0.2 mm. The skinfold measurements were taken once for all eight skinfold thicknesses (pectoralis, axillar, triceps, subscapular, abdomen, suprailiac, front thigh, and medial calf) and then the procedure was repeated twice more by the same investigator; the mean of the three values was then used for the analyses. The timing of the taking of the skinfold measurements was standardized to ensure reliability. According to Becque and colleagues (Becque, Katch, & Moffatt, 1986), readings were performed 4 s after applying the calliper. An intra-tester reliability check was conducted on 27 male and 11 female runners before testing. The intra-class correlation (ICC) within the two judges was excellent for both men and women for all anatomical measurement sites (ICC > 0.9). For the sum of eight skinfolds for measurer 1, the bias (average difference between measure 1 and 2) was –0.515, standard deviation of the average difference was 1.492, and 95% limits of agreement were between –3.439 and 2.409 (Knechtle et al., 2010b). Percent body fat was calculated using the anthropometric formula according to Ball and colleagues (Ball, Altena, & Swan, 2004):

$$\begin{aligned}\text{Percent body fat} = 0.465 &+ 0.180 * (\Sigma 7\text{SF}) \\ &- 0.000246 * (\Sigma 7\text{SF})^2 \\ &+ 0.0661 * (\text{age}),\end{aligned}$$

where $\Sigma 7\text{SF} =$ sum of seven skinfold thicknesses (pectoralis, axillar, triceps, subscapular, abdomen, suprailiac, front thigh).

Statistical analysis

Data are presented as means and standard deviations (s). The anthropometric and training variables of both the Triple Iron ultra-triathletes and the Ironman triathletes were compared using the Mann-Whitney U-test. Race time was also expressed as a percentage of the course records for both races. A power calculation was performed following Gatsonis and Sampson (1989). To achieve a power of 80% (two-sided Type I error of 5%) to detect a minimal association between race time and anthropometric characteristics of 20% (i.e. coefficient of determination $r^2 = 0.2$), a sample of 40 participants was required. Potential associations between anthropometric characteristics, training variables, and both split times in the race and total race time were investigated using Pearson correlation analysis. In a first step, a correlation analysis was performed with the anthropometric and training variables to exclude co-linearity of predictor variables; multicollinearity between predictor variables was excluded with $r > 0.9$. In a second step, a multiple linear regression analysis (forward selection, P of F for inclusion < 0.05, P of F for exclusion > 0.1) was assessed with race time as the dependent variable separately for Ironman triathletes and Triple Iron ultra-triathletes using the significant variables after bivariate analysis. Statistical significance was set at $P < 0.05$.

Results

The Ironman triathletes completed the 3.8 km swim, 180 km cycle, and 42.195 km run in 689 ($s = 79$) min. Expressed as a percentage of the course record of Olivier Bernhard (SUI) in 2000 of 492 min, they performed within 140% ($s = 16$) of the course record. The Triple Iron ultra-triathletes finished the 11.6 km swim, 540 km cycle, and 126.6 km run in 2811 ($s = 379$) min, corresponding to 147% ($s = 20$) of the course record of 1907 min of Luis Wildpanner (AUT) in 2003. Performances expressed as percentages of the course records were no different for the two groups of athletes. The split times for the swim ($r = 0.73$), bike ($r = 0.88$), and run section ($r = 0.85$) were highly significantly related to total race time in the Ironman triathletes ($P < 0.001$). For the Triple Iron ultra-triathletes, the split time for the swim was significantly related to total race time ($r = 0.27$, $P < 0.05$); the split time for the bike ($r = 0.86$) and run section ($r = 0.91$) were highly significantly associated with the total race time ($P < 0.001$).

The Triple Iron ultra-triathletes were smaller and had shorter limbs than the Ironman triathletes (see Table I). The ratio of leg length to height, however, was not different between the two groups. Body mass index, the circumferences of upper arm, thigh, and calf were larger in the Triple Iron ultra-triathletes. There was no difference in percent body fat between the two groups. The Triple Iron ultra-triathletes invested significantly more weekly training hours than the Ironman triathletes. In all three disciplines, the Triple Iron ultra-triathletes were training both more hours and kilometres. Regarding the speed during training, the Triple Iron ultra-triathletes ran more slowly than the Ironman triathletes. During the races, the Triple Iron ultra-triathletes swam, cycled, and ran more slowly than the Ironman triathletes.

In the bivariate analysis (see Table II), the circumference of upper arm, percent body fat, the sum of eight skinfolds, weekly cycling hours, weekly cycling kilometres, weekly running hours, and weekly running kilometres were related to race time for the Triple Iron ultra-triathletes. For the Ironman triathletes, body mass, body mass index, the circumferences of upper arm, thigh, and calf, percent body fat, the sum of eight skinfolds, speeds when swimming, cycling, and running during training were related to race time. In the multivariate analysis for Triple Iron ultra-triathletes (see Table III), percent body fat, weekly training hours, weekly cycling kilometres, and weekly running kilometres were related to race time. In the multivariate analysis for Ironman triathletes (see Table IV), the circumference of upper arm, percent body fat, and the speed in cycling during training were associated with Ironman race time.

Table I. Comparison between Triple Iron ultra-triathletes and Ironman triathletes.

	Triple Iron ultra-triathletes ($n = 64$)	Ironman triathletes ($n = 71$)
Body mass (kg)	77.8 (8.2)	77.5 (8.9)
Height (m)	1.78 (0.06)*	1.81 (0.06)
Body mass index ($kg \cdot m^{-2}$)	24.5 (2.1)*	23.7 (2.2)
Length of leg (cm)	85.1 (3.9)*	86.3 (5.1)
Length of arm (cm)	79.4 (2.7)*	81.3 (4.2)
Ratio of leg length to height	47.8 (2.9)	47.7 (3.1)
Circumference of upper arm (cm)	30.6 (2.2)*	29.9 (2.7)
Circumference of thigh (cm)	56.0 (3.6)**	54.4 (2.9)
Circumference of calf (cm)	39.0 (2.4)**	37.3 (2.3)
Percent body fat (%)	14.5 (3.4)	15.6 (4.7)
Sum of eight skinfolds (mm)	78.0 (24.8)	82.2 (35.0)
Training volume (hours per week)	19.3 (8.8)**	13.7 (5.6)
Hours of swimming per week in training	3.1 (1.8)*	2.4 (1.2)
Kilometres of swimming per week in training	8.4 (4.5)**	5.7 (2.9)
Speed in swimming during training ($km \cdot h^{-1}$)	2.8 (0.6)	2.8 (0.6)
Hours of cycling per week in training	10.3 (5.8)**	6.7 (2.4)
Kilometres of cycling per week in training	278.7 (139.9)**	181.6 (71.1)
Speed in cycling during training ($km \cdot h^{-1}$)	27.5 (3.1)	27.9 (2.8)
Hours of running per week in training	5.8 (2.1)*	4.7 (4.6)
Kilometres of running per week in training	60.7 (21.6)**	43.9 (17.4)
Speed in running during training ($km \cdot h^{-1}$)	10.5 (1.5)**	11.1 (1.2)
Speed in swimming during the race ($km \cdot h^{-1}$)	2.8 (0.4)*	3.0 (0.4)
Speed in cycling during the race ($km \cdot h^{-1}$)	24.1 (3.1)**	31.3 (3.2)
Speed in running during the race ($km \cdot h^{-1}$)	6.7 (1.4)**	10.1 (1.6)

Note: Results are presented as mean (s). $^*P < 0.05$, $^{**}P < 0.01$.

Table V shows the correlations of the anthropometric characteristics and the training variables with the split times and total race time for Triple Iron ultra-triathletes in the bivariate analysis. The circumference of the upper arm was related to the speed in swimming and cycling during training and to the run split and total race times. The circumference of the thigh was related to the speed in swimming and cycling during training. Percent body fat was associated with the speed in swimming and cycling during training. The sum of skinfolds was related to the speed in swimming and weekly cycling kilometres. Percent body fat and the sum of skinfolds

Table II. Correlation of anthropometric and training characteristics with race time for Triple Iron ultra-triathletes ($n = 64$).

	Triple Iron ultra-triathletes ($n = 64$)		Ironman triathletes ($n = 71$)	
	r	P	r	P
Body mass	0.24		0.33	$P = 0.0049$
Height	0.09		0.00	
Body mass index	0.21		0.42	$P = 0.0003$
Length of leg	0.05		0.07	
Length of arm	0.05		−0.13	
Ratio of leg length to height	−0.03		0.07	
Circumference of upper arm	0.33	$P = 0.0081$	0.39	$P = 0.0008$
Circumference of thigh	0.14		0.29	$P = 0.0135$
Circumference of calf	0.10		0.24	$P = 0.0450$
Percent body fat	0.40	$P = 0.0015$	0.49	$P < 0.0001$
Sum of eight skinfolds	0.42	$P = 0.0007$	0.45	$P < 0.0001$
Training volume in hours per week	−0.20		−0.12	
Hours of swimming per week in training	0.24		−0.15	
Kilometres of swimming per week in training	0.09		−0.17	
Speed in swimming during training	0.05		−0.30	$P = 0.0108$
Hours of cycling per week in training	−0.27	$P = 0.0312$	−0.06	
Kilometres of cycling per week in training	−0.33	$P = 0.0083$	−0.10	
Speed in cycling during training	−0.03		−0.27	$P = 0.0244$
Hours of running per week in training	−0.29	$P = 0.0188$	0.01	
Kilometres of running per week in training	−0.35	$P = 0.0052$	−0.19	
Speed in running during training	−0.17		−0.24	$P = 0.0473$

Note: P-values are shown when there is a significant association.

Table III. Multiple linear regression analysis with race time as the dependent variable for the Triple Iron ultra-triathletes ($n = 64$).

	ß	SE	P
Percent body fat	0.22	10.59	0.022
Training volume in hours per week	−0.51	5.31	<0.0001
Kilometres of cycling during training per week	0.61	10.82	<0.0001
Kilometres of running during training per week	−0.54	57.80	<0.0001

Note: ß = regression coefficient; SE = standard error of the regression coefficient. The coefficient of determination (R^2) of the model was 30%.

Table IV. Multiple linear regression analysis with race time as the dependent variable for the Ironman triathletes ($n = 71$).

	ß	SE	P
Circumference of upper arm	0.28	2.93	0.006
Percent body fat	0.42	1.66	<0.0001
Speed in cycling during training	−0.24	2.72	0.012

Note: ß = regression coefficient; SE = standard error of the regression coefficient. The coefficient of determination (R^2) of the model was 38%.

were related to bike split time, run split time, and total race time. Percent body fat was not related to weekly training hours.

For the Ironman triathletes (see Table VI), the circumference of the upper arm was related to weekly training hours, to running speed during training, to both bike and run split times, and to total race time. The circumferences of the thigh and calf were associated with weekly running hours, with run split time, and with total race time. Percent body fat and the sum of eight skinfolds were significantly and positively related to swim split time, bike split time, run split time, and total race time. The circumferences of the limbs showed no association with percent body fat; percent body fat was not related to weekly training hours.

Discussion

In the present study, we compared the anthropometric and training characteristics of Ironman triathletes and Triple Iron ultra-triathletes, and assessed whether anthropometric and training variables were related to race performance. Both the Ironman triathletes and the Triple Iron ultra-triathletes finished their races in ~140% of the course record; therefore, we assume that the two groups were comparable regarding the association of predictor variables with performance. The Ironman triathletes finished the race within 689 min, which was also comparable to another sample of 42 Ironman triathletes finishing their race within 661 min (Neubauer et al., 2008). The final race time of 2811 min for the Triple Iron ultra-triathletes was comparable to the 2712 min for Triple Iron ultra-triathletes competing on a different course and race in Austria (Knechtle et al., 2007a).

Table V. Correlation of anthropometric and training characteristics including total race time for Triple Iron ultra-triathletes ($n = 64$).

	Circumference of upper arm	Circumference of thigh	Circumference of calf	Percent body fat	Sum of eight skinfolds
Training volume in hours per week	−0.10	−0.09	−0.13	−0.13	−0.18
Hours of swimming per week	0.06	0.00	−0.08	−0.03	−0.07
Kilometres of swimming per week	−0.04	−0.11	−0.14	−0.13	−0.17
Speed in swimming during training	−0.31, $P = 0.0127$	−0.30, $P = 0.0162$	−0.17	−0.32, $P = 0.0106$	−0.33, $P = 0.0080$
Hours of cycling per week	−0.13	−0.10	−0.17	−0.15	−0.20
Kilometres of cycling per week	−0.20	−0.22	−0.20	−0.22	−0.26, $P = 0.0409$
Speed in cycling during training	−0.37, $P = 0.0028$	−0.43, $P = 0.0004$	−0.22	−0.27, $P = 0.0361$	−0.25
Hours of running per week	−0.08	−0.11	−0.02	−0.09	−0.14
Kilometres of running per week	−0.14	−0.16	−0.04	−0.13	−0.15
Speed in running during training	−0.18	−0.19	−0.06	−0.17	−0.09
Swim split time in the race	−0.13	−0.04	0.04	0.11	0.14
Bike split time in the race	0.17	0.02	0.02	0.32, $P = 0.0117$	0.33, $P = 0.0089$
Run split time in the race	0.45, $P = 0.0003$	0.20	0.15	0.44, $P = 0.0003$	0.47, $P = 0.0001$
Total race time	0.33, $P = 0.0081$	0.14	0.10	0.40, $P = 0.0015$	0.42, $P = 0.0007$

Note: *P*-values are shown when there is a significant association.

Table VI. Correlation of anthropometric and training characteristics including total race time for Ironman triathletes ($n = 71$).

	Circumference of upper arm	Circumference of thigh	Circumference of calf	Percent body fat	Sum of eight skinfolds
Training volume in hours per week	−0.41, $P = 0.0005$	−0.36, $P = 0.0019$	−0.31, $P = 0.0093$	0.17	0.12
Hours of swimming per week	0.03	0.06	−0.03	−0.03	0.00
Kilometres of swimming per week	0.15	0.17	0.02	−0.07	−0.02
Speed in swimming during training	−0.13	−0.19	−0.16	−0.11	−0.11
Hours of cycling per week	0.20	0.13	0.15	−0.15	−0.13
Kilometres of cycling per week	0.20	0.18	0.17	−0.16	−0.14
Speed in cycling during training	−0.04	0.05	0.02	−0.02	0.01
Hours of running per week	−0.10	0.01	0.04	−0.04	−0.08
Kilometres of running per week	−0.09	0.00	0.08	−0.19	−0.20
Speed in running during training	−0.28, $P = 0.0184$	−0.15	−0.18	−0.09	−0.10
Swim split time in the race	0.16	0.13	0.04	0.38, $P = 0.0012$	0.30, $P = 0.0124$
Bike split time in the race	0.29, $P = 0.0127$	0.19	0.15	0.47, $P < 0.0001$	0.43, $P = 0.0002$
Run split time in the race	0.47, $P < 0.0001$	0.38, $P = 0.0011$	0.33, $P = 0.0045$	0.36, $P = 0.0019$	0.36, $P = 0.0022$
Total race time	0.39, $P = 0.0008$	0.29, $P = 0.0135$	0.24, $P = 0.0450$	0.49, $P < 0.0001$	0.45, $P < 0.0001$

Note: *P*-values are shown when there is a significant association.

Regarding the anthropometry between the two groups, the Triple Iron ultra-triathletes were smaller and had shorter limbs than the Ironman triathletes. However, the ratio of leg length to height was not different between the two groups. Height and the length of limbs including the ratio of leg length to height showed no association with race time in both the Triple Iron ultra-triathletes and the Ironman triathletes. The circumferences of the limbs were larger in the Triple Iron ultra-triathletes than the Ironman triathletes. However, large limb circumferences appear not to enhance performance in Triple Iron ultra-triathletes, where circumference of the upper arm was only related to the split time in the run and to total race time, whereas all limb circumferences were related to both the split time in the run and to total race time for the Ironman triathletes. Thus the circumferences of the limbs would appear to be more important for endurance performance than the length of the limbs.

When we compared the age and anthropometric characteristics of the Ironman triathletes with another sample of 42 Ironman triathletes (Neubauer et al., 2008), our athletes had a higher body fat percentage (15.2% vs. 11.8%). Percent body fat was related to both split times and total race time in both the Triple Iron ultra-triathletes and the Ironman triathletes. The sum of eight skinfolds was not included in the multiple linear regression analysis due to multicollinearity between percent body fat and the sum of eight skinfolds. This finding corresponds well with previous findings that body fat was related to performance times in triathletes, including short-distance triathletes (Landers, Blanksby, Ackland, & Smith, 2000; Sleivert & Rowlands, 1996), Ironman triathletes (Knechtle et al., 2010c, 2010d, 2011a), and Triple Iron ultra-triathletes (Knechtle et al., 2009b)

The circumferences of the limbs were different in the Triple Iron ultra-triathletes and the Ironman triathletes, with the latter having smaller circumferences. In the Ironman triathletes, all circumferences of the limbs were significantly and negatively related to weekly training hours and the circumference of the upper arm was significantly and negatively associated with the running speed during training. All limb circumferences were significantly and positively related to both the split time in the run and to the total race time in the bivariate analysis. In the Triple Iron ultra-triathletes, the circumference of the upper arm was related to both the split time in the run and to total race time. In the multivariate analysis, however, the circumference of the upper arm was not related to total race time in the Triple Iron ultra-triathletes, but to race time in the Ironman triathletes. When we compare the limb circumferences for the Triple Iron ultra-triathletes with the Ironman triathletes, we assume that training led to a decrease in limb circumferences in the Ironman triathletes, but not in the Triple Iron ultra-triathletes. The Ironman triathletes seemed then to profit from the reduced limb circumferences in the race, but not the Triple Iron ultra-triathletes, where only the upper arm circumference was related to the split time in the run and to total race time. In recent studies on ultra-endurance runners, the circumference of the upper arm was related to running performance (Knechtle, Duff, Welzel, & Kohler, 2009a; Knechtle, Knechtle, Schulze, & Kohler, 2007b). The circumference of the upper arm was related to the split time in the run and to total race time in the bivariate analysis, but is was not related to total race time in the Triple Iron ultra-triathletes in the multivariate analysis. A recent study assumed that Triple Iron ultra-triathletes were close to runners regarding the relationship of anthropometry with race performance (Knechtle et al., 2009b). In a recent study comparing Triple Iron ultra-triathletes with 100-km ultra-marathoners, however, the Triple Iron ultra-triathletes were not similar to ultra-runners in anthropometric measures and training variables (Knechtle, Knechtle, & Rosemann, 2010e).

We believe that training volume is more important for a fast race time among Triple Iron ultra-triathletes than their anthropometry. The Triple Iron ultra-triathletes invested more volume in training, but were not training faster than the Ironman triathletes. Indeed, they were running slower during training. For the Triple Iron ultra-triathletes, the kilometres of cycling and running during training were related to the total race time, whereas the speed in cycling during training was related to race time in Ironman triathletes. In a recent study of 29 Triple Iron ultra-triathletes, the mean weekly training volume was not related to race time (Knechtle et al., 2009b). These disparate findings might be explained by the fact that in the present investigation 64 athletes were included and statistical analysis was influenced. In contrast to the Triple Iron ultra-triathletes, the speed in training in all three disciplines was related to race time in the Ironman triathletes. That the speed in cycling during training was related to race time in the Ironman triathletes in the multivariate analysis is at odds with previous research. O'Toole (1989) concluded that distance appeared to be more important than pace in training. For cycling especially, Gulbin and Gaffney (1999) demonstrated that the weekly cycling distances and longest training rides were associated with Ironman performance times. Hendy and Boyer (1995), however, found no clear pattern regarding training and performance in cycling.

We found a significant and positive association between percent body fat and speed in swimming and cycling training for Triple Iron ultra-triathletes. One might assume that training leads to reduced body fat, since Legaz and Eston (2005) showed that intense running training led to decreased skinfold thickness. However, correlation analysis does not prove cause and effect and the reduced body fat could also be due to diet and, as a result of the lower body fat and lower body mass, athletes were able to train faster. This might pertain in particular to the Ironman triathletes, in whom percent body fat showed no association with training variables; however, the limb circumferences were related to weekly training hours. Since percent body fat was not related to limb circumferences, we assume that an adaptation in skeletal muscle rather than a reduction in body fat occurred during training.

A limitation in the anthropometric measurementsa is the fact that not all measurements were performed following International Society of Advancement of Kinanthropometry (ISAK) recommendations. Another limitation was that weather conditions were not included, and weather has an influence on race outcome of ultra-runners (Wegelin & Hoffman, 2011).

In conclusion, the Triple Iron ultra-triathletes were smaller, had shorter limbs, larger limb circumferences, and more muscle mass than the Ironman triathletes. Also, the Triple Iron ultra-triathletes invested more training hours and kilometres during training, although they competed more slowly during their race. Both the Triple Iron ultra-triathletes and the Ironman triathletes seemed to profit from low body fat. The Triple Iron ultra-triathletes were relying, however, more on volume in cycling and running for a fast race time where intensity in cycling seemed to be related to race time in the Ironman triathletes.

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