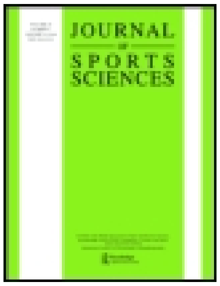

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Similarities and differences in anthropometry and training between recreational male 100-km ultra-marathoners and marathoners

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Abstract

Several recent investigations showed that the best marathon time of an individual athlete is also a strong predictor variable for the race time in a 100-km ultra-marathon. We investigated similarities and differences in anthropometry and training characteristics between 166 100-km ultra-marathoners and 126 marathoners in recreational male athletes. The association of anthropometric variables and training characteristics with race time was assessed by using bi- and multi-variate analysis. Regarding anthropometry, the marathoners had a significantly lower calf circumference ($P < 0.05$) and a significantly thicker skinfold at pectoral ($P < 0.01$), axilla ($P < 0.05$), and suprailiacal sites ($P < 0.05$) compared to the ultra-marathoners. Considering training characteristics, the marathoners completed significantly fewer hours ($P < 0.001$) and significantly fewer kilometres ($P < 0.001$) during the week, but they were running significantly faster during training ($P < 0.001$). The multi-variate analysis showed that age ($P < 0.0001$), body mass ($P = 0.011$), and percent body fat ($P = 0.019$) were positively and weekly running kilometres ($P < 0.0001$) were negatively related to 100-km race times in the ultra-marathoners. In the marathoners, percent body fat ($P = 0.002$) was positively and speed in running training ($P < 0.0001$) was negatively associated with marathon race times. In conclusion, these data suggest that performance in both marathoners and 100-km ultra-marathoners is inversely related to body fat. Moreover, marathoners rely more on speed in running during training whereas ultra-marathoners rely on volume in running training.

Keywords: *endurance, athlete, body fat, skinfold thickness*

Introduction

Ultra-marathon running has been growing in popularity in recent years (Hoffman, 2010; Hoffman, Ong, & Wang, 2010; Hoffman & Wegelin, 2009; Kao et al., 2008; Knechtle, Rüst, Rosemann, & Lepers, 2011b; Zouhal et al., 2009). The strongest increase can be found in the class of the master athletes as several recently published investigations on 161-km (Hoffman, 2010; Hoffman & Wegelin, 2009) and 100-km (Knechtle et al., 2011b) ultra-marathoners showed. Several studies have attempted to define predictor variables for an ultra-marathon performance (Knechtle, Duff, Welzel, Kohler, 2009b; Knechtle, Knechtle, Rosemann, & Lepers, 2010b; Knechtle, Knechtle, Rosemann, & Senn, 2011a; Knechtle, Wirth, Knechtle, Zimmermann, & Kohler, 2009a; Millet et al., 2011; Noakes, Myburgh, & Schall, 1990). Variables of physiology (Millet et al., 2011; Noakes et al., 1990), anthropometry (Knechtle et al., 2009b, 2010b, 2011a), previous experience (Knechtle et al., 2009a, 2011a; Knechtle, Knechtle, & Rosemann, 2010c; Knechtle, Wirth, Knechtle, & Rosemann, 2010d; Knechtle, Knechtle, Rosemann, & Lepers, 2011c), training (Knechtle et al., 2010b, 2010c, 2010d, 2011a, 2011c) and age (Knechtle et al., 2010b, 2011b) seem to have an influence on race outcome in ultra-marathoners.

Regarding anthropometric variables and training characteristics, a previous personal best marathon time was a strong predictor variable for 100-km ultra-marathoners (Knechtle et al., 2010b, 2010d), 24-hours ultra-marathoners (Knechtle et al., 2009a, 2011c), and multi-stage mountain ultra-marathoners (Knechtle et al., 2010c). However, these previous findings raise the question whether similarities do exist between ultra-marathoners and marathoners. Considering predictor variables for running performance up to the marathon distance, the lactate value at both 10 $km \cdot h^{-1}$ and 22 $km \cdot h^{-1}$ running speed

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(Legaz Arrese, Munguía Izquierdo, & Serveto Galindo, 2006), maximum oxygen uptake (Hagan, Smith, & Gettman, 1981), body mass (Hagan et al., 1981, Loftin et al., 2007), the skinfold of the lower leg (Arrese & Ostáriz, 2006, Knechtle, Knechtle, Barandun, Rosemann, & Lepers, 2011d), the upper arm circumference (Knechtle et al., 2009b), the number of previously completed marathons (Hagan, Upton, Duncan, & Gettman, 1987), the number of daily workouts (Hagan et al., 1981, 1987), training runs of long duration (Hagan et al., 1981), the mean running distance per week (Hagan et al., 1987), the mean running kilometres per day (Hagan et al. 1987), the longest running distance covered per training session (Yeung, Yeung, & Wong, 2011), the duration of training (Hagan et al., 1987), the kilometres completed per week (Billat, Demarle, Slawinski, Paiva, & Koralsztein, 2011; Hagan et al., 1987), and the training pace (Hagan et al., 1987, McKelvie, Valliant, & Asu, 1985) have been shown to be positively related to marathon race times.

The aim of the present study was to investigate whether 100-km ultra-marathoners and marathoners were similar regarding anthropometry and training. Our hypothesis was that these two groups of athletes would show no significant differences regarding both their training parameters and anthropometric measures. To test this hypothesis, we compared anthropometric characteristics and training variables between a sample of male marathoners and a different sample of male 100-km ultra-marathoners. Furthermore, we correlated anthropometric characteristics and training variables to race time by using bi- and multi-variate analysis in order to find similarities or differences in predictor variables for each distance.

Materials and methods

Participants

All the male ultra-marathoners in the '100 km Lauf Biel' and all the male runners at the 'Basel Marathon' in Basel, Switzerland, were invited by means of an electronic newsletter sent by the organiser three months before the start of the race. In addition, detailed information was available on the race website about the planned investigation. Since participation in ultra-endurance events is low per race (Knechtle, Knechtle, & Lepers, 2011f), data were collected from four consecutive years (2008 to 2011) to increase the size of the 100-km ultra-marathon sample. We focussed on recreational athletes, defined as an athlete pursuing a regular occupation, performing his sport during leisure time, having no sponsors and earning his livelihood neither through sponsorship nor by prize money. In the 'Basel Marathon', athletes were recruited from two consecutive years (2010 to 2011). In the '100 km Lauf Biel', a total of 166 participants were recruited, in the 'Basel Marathon', a total of 126 male marathoners were measured pre-race. No athlete was included twice and no athlete competed in both races. The study was approved by the Institutional Review Board for use of Human Subjects of the Canton of St. Gallen, Switzerland. The athletes were informed of the experimental procedures and they all gave their written informed consent to participate in the study.

The races

The '100 km Lauf Biel' in Biel, Berne, Switzerland, generally takes place during the night of the first weekend in June from Friday to Saturday. The athletes start the 100-km ultra-marathon at 10:00 p.m. During these 100 km with a total climb of altitude of 645 metres, the organiser provided a total of 17 aid stations offering an abundant variety of food and beverages such as carbohydrate-electrolyte beverages, tea, soup, Coca Cola®, water, bananas, oranges, bread and energy bars. The athletes are allowed to be supported by a cyclist in order to have additional food and clothing, if necessary. In the 'Basel Marathon', the athletes had to run 42.2 km covering two laps on asphalt with a total altitude of 200 m. The organiser offered food and beverages at periodical intervals.

Measurements and calculations

All participants were asked to document three months before the start of both the '100 km Lauf Biel' and the 'Basel Marathon', their training units showing duration in minutes and distance in kilometres. To ease the documentation of the training variables and also to increase validity of the data, the investigators provided an electronic file where the participants could insert each training unit with distance, duration and speed, expressed in $km \cdot h^{-1}$. The investigators then calculated the mean weekly hours, weekly kilometres and speed during running training sessions in the pre-race preparation. The participants also reported the number of completed marathons. In addition, they provided their personal best marathon time defined as the best time ever achieved in a marathon regardless the course and the environmental conditions.

The afternoon before the start of each race, the anthropometric characteristics (*i.e.* body mass, body height, the circumferences of the limbs and the thicknesses of skinfolds at pectoral, mid-axilla, triceps, subscapular, abdominal, suprailiacal, front thigh and medial calf site) were measured. The circumferences of the limbs as well as all skinfold thicknesses were measured on the right side of the body. With this data, body mass index, percent body fat and skeletal muscle mass, using anthropometric methods, were calculated. Body mass was measured using a commercial scale (Beurer BF 15, Beurer, Ulm, Germany) to the nearest 0.1 kg. Body height was determined using a stadiometer (Tanita HR 001 Portable Height Measure, Tanita Europe, Amsterdam, Netherlands) to the nearest 1.0 cm. The circumferences of the limbs were measured using a non-elastic tape measure (KaWe CE, Kirchner und Welhelm, Germany) to the nearest 0.1 cm. The circumference of the upper arm was measured at mid-arm, the circumference of the thigh was taken at mid-thigh and the circumference of the calf was measured at maximum girth. All skinfold data were obtained using a skinfold calliper (GPM-Hautfaltenmessgerät, Siber & Hegner, Zurich, Switzerland) and recorded to the nearest 0.2 mm. The skinfold calliper measures with a pressure of 0.1 Mpa $\pm$ 5% over the whole measuring range. The skinfold measurements were taken once for all skinfold sites. The anatomical sites for the skinfold thicknesses were pectoral (anterior axillary line), mid-axilla (vertical), triceps (in the middle of the upper arm), subscapular (at *angulus inferior scapulae*), abdominal (vertical, right to the navel), suprailiacal (at anterior axillary), front thigh (mid-thigh) and medial calf (maximum girth). The investigators identified the correct anatomical site using orientation with finger- and hand-breadth from prominent anatomical sites, such as a prominent protuberance or insertion of a tendon. The skinfolds were taken three times and the mean of the three results was used for the analyses. The available time for taking the skinfold measurement was standardised to ensure reliability. According to Becque, Katch, and Moffat (1986), readings were performed 4 sec after applying the calliper. One trained investigator took all the skinfold measurements as inter-tester variability is a major source of error in skinfold measurement. Intra- and inter- investigator agreement was assessed from 27 male runners prior to an ultra-marathon, based on measurements taken by two experienced primary care physicians (Knechtle et al., 2010a). Intra-class correlation (ICC) within the two investigators was excellent for all anatomical measurement sites and for various summary measurements of skinfold thickness. Agreement tended to be higher within than between investigators, and reached good reliability with ICC = 0.99 (0.99–1.00 95% confidence interval) for the summary measurements of skinfold thickness between investigators. ICC for investigator 1 versus investigator 1 and for investigator 2 versus investigator 2 for the single skinfold thicknesses were between 0.98 and 0.99, respectively. For the sum of seven and eight skinfolds, respectively, ICC was 0.99–1.00. For the sum of eight skinfolds for investigator 1, bias (*i.e.* average difference between investigator 1 and investigator 2) was -0.515 mm, standard deviation of the average difference was 1.492 mm; and 95% limits of agreement were between -3.439 mm and 2.409 mm. Percent body fat was estimated using the anthropometric formula according to Ball, Altena, and Swan (2004) for males with percent body fat $= 0.465 + 0.180 \times (\Sigma 7SF) - 0.0002406 \times (\Sigma\ 7SF)^2 + 0.0661 \times (age)$. Σ7SF is the sum of seven skinfold thickness of pectoralis, axilla, triceps, subscapular, abdomen, suprailiacal and thigh (thickness in mm; age in years). The predicted residual sum of squares (PRESS) r^2 was high (0.90) and the PRESS standard error of estimates (SEE) was excellent (2.2% at the mean) for the equation when applied to a sample of 160 men. Skeletal muscle mass (SMM) was estimated using the formula of Lee et al. (2000) with $SMM = Ht \times (0.00744 \times CAG^2 + 0.00088 \times CTG^2 + 0.00441 \times CCG^2) + 2.4 \times sex - 0.048 \times age + race + 7.8$, where Ht = height, CAG = skinfold-corrected upper arm girth, CTG = skinfold-corrected thigh girth, CCG = skinfold-corrected calf girth, sex = 1 for male; age is in years; race = 0 for white men and 1 for black men. This equation was validated using magnetic resonance imagining (MRI) to determine skeletal muscle mass. There was a high correlation between the predicted skeletal muscle mass and the MRI-measured skeletal muscle mass ($r^2 = 0.83$, $P < 0.0001$, SEE = 2.9 kg). The correlation between the measured and the predicted skeletal muscle mass difference and the measured skeletal muscle mass was significant ($r^2 = 0.90$, $P = 0.009$).

Statistical analysis

Data were analysed using SPSS software version 15 (SPSS Inc., Chicago, USA). The Shapiro-Wilk test was used to check for normal distribution. Data are presented as mean $\pm$ standard deviation *(s)*. The coefficient of variation (CV) of performance (CV% = $100 \times s$/mean) was calculated. The coefficient of variation describes the magnitude sample values and the variation within them. Data for the 100-km ultra-marathoners and the marathoners were compared using the Student's T-test. In a first step, to investigate a potential association between the anthropometric characteristics and the training variables with performance, the relationship between race time for the 100-km ultra-marathoners and marathon race time for the marathoners as the dependent variable and the variables of age, anthropometry, training and previous experience was investigated using bi-variate Pearson correlation analysis. For the strength of a correlation, $r > 0.70$ indicated a very strong, $r = 0.40$ to 0.69 a strong, $r = 0.30$ to 0.39 a moderate, $r = 0.20$ to 0.29 a weak and $r = 0.01$ to 0.19 a negligible relationship, respectively. In order to reduce the variables for the multi-variate analysis, Bonferroni correction was applied ($P < 0.0023$ for 21 variables). In a second step, all significant variables after bi-variate analysis entered the multiple linear regression analysis (stepwise, forward selection, P of F for inclusion < 0.05, P of F for exclusion > 0.1). Multi-collinearity between the predictor variables was excluded with $r > 0.9$. A power calculation was performed according to 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. An alpha level of 0.05 was used to indicate significance for all statistical tests.

Results

The 100-km ultra-marathoners completed the '100 km Lauf Biel' within 708 ($s = 124$) min (CV = 17.5%), running at a mean speed of 8.7 ($s = 1.5$) $km \cdot h^{-1}$. Expressed in percent of the course record of 6 h 37 min, set by Peter Camenzind in 1996, they completed the race within 178 ($s = 31$) % of the course record. The marathoners finished the 'Basel Marathon' within 231 ($s = 31$) min (CV = 13.4%), running at a speed of 11.1 ($s = 1.4$) $km \cdot h^{-1}$. During the race, the marathoners were running significantly faster than the 100-km ultra-marathoners ($P < 0.0001$). Expressed in percent of the course record of 2 h 38 min, achieved by Andreas Schur in 2010, the marathoners finished within 146 ($s = 19$) % of the course record. When the performance was compared, expressed in percent of the course record, the marathoners were significantly faster than the 100-km ultra-marathoners ($P < 0.0001$).

In the marathoners, 92 athletes (73%) had previously completed at least one marathon whereas 161 of the 100-km ultra-marathoners (95%) had finished a marathon ($P < 0.0001$). The personal best time in a marathon was significantly faster in the 100-km ultra-marathoners than in the marathoners ($P < 0.05$). In the ultra-marathoners, the number of completed marathons showed a moderate positive relationship ($r = 0.39$, $P < 0.0001$) with age. In the marathoners, the number of completed marathons was weakly positively associated ($r = 0.28$, $P = 0.0069$) with age.

Regarding the anthropometric characteristics, the marathoners had a smaller calf circumference and a thicker skinfold thickness at pectoral, axilla, and suprailiacal sites compared to the 100-km ultra-marathoners (Table I). For the training variables, the marathoners completed significantly fewer hours and fewer kilometres during their weekly training, but were running significantly faster than the 100-km ultra-marathoners during training (Table I). The single skinfold thicknesses were, in both the 100-km ultra-marathoners and the marathoners, highly significantly correlated to both the sum of skinfolds and percent body fat ($r > 0.9$). Thus, for the skinfold thicknesses and body fat, only percent body fat could be included in the multi-variate regression analysis (Table II).

In the multi-variate analysis, age, body mass, percent body fat and weekly running kilometres were related to the 100-km race time of the ultra-marathoners (Table III). In the marathoners, percent

Table I. Comparison of anthropometry and training between the 100-km ultra-marathoners and the marathoners.

	100-km ultra-marathoners ($n = 166$)	Marathoners ($n = 126$)	Significance
Age (years)	45.8 (9.5)	42.8 (10.8)	
Body mass (kg)	75.0 (9.4)	73.9 (8.0)	
Body height (m)	1.79 (0.07)	1.78 (0.06)	
Body mass index ($kg \cdot m^{-2}$)	23.4 (2.1)	23.4 (2.2)	
Circumferences			
Upper arm (cm)	29.5 (2.0)	29.2 (1.9)	
Thigh (cm)	54.8 (3.2)	54.9 (2.6)	
Calf (cm)	38.6 (2.3)	37.9 (2.3)	*
Skinfold thicknesses			
Pectoral (mm)	7.7 (4.0)	8.1 (3.0)	**
Axilla (mm)	9.2 (3.7)	9.6 (2.8)	*
Triceps (mm)	8.1 (3.0)	7.8 (2.6)	
Subscapular (mm)	11.1 (4.6)	10.5 (4.0)	
Abdominal (mm)	16.4 (8.2)	15.4 (6.3)	
Suprailiacal (mm)	16.7 (7.3)	18.3 (7.1)	*
Thigh (mm)	11.6 (5.5)	12.0 (5.0)	
Calf (mm)	5.9 (2.6)	6.1 (2.4)	
Sum (mm)	86.6 (32.4)	87.4 (27.2)	
Percent body fat (%)	16.2 (4.3)	16.2 (3.7)	
Skeletal muscle mass (kg)	38.9 (3.9)	38.1 (3.9)	
Number of completed marathons (n)	34 (73) ($n = 161$)	12 (21) (n = 92)	***
Personal best marathon time (min)	207 (31)	216 (32)	*
Weekly running hours (h)	8.1 (7.1)	4.8 (2.5)	***
Weekly running kilometres (km)	70.5 (27.6)	44.7 (24.7)	***
Speed in running training ($km \cdot h^{-1}$)	10.2 (2.2)	11.0 (1.4)	***

Note: Results are presented as mean (s). * = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$.

Table II. Association of anthropometric and training characteristics with race time for the 100-km ultra-marathoners and the marathoners. Variables with *P*-values of <0.0023 are inserted in the multi-variate analysis ($n = 21$ variables).

	100-km ultra-marathoners ($n = 166$)		Marathoners ($n = 126$)	
	r	***P***	***r***	***P***
Age	0.26	0.0005	0.23	0.0096
Body mass	0.27	0.0004	0.24	0.0069
Body height	0.02	0.77	−0.01	0.95
Body mass index	0.32	<0.0001	0.27	0.0019
Circumferences				
Upper arm	0.21	0.0072	0.16	0.067
Thigh	0.14	0.06	0.23	0.0088
Calf	0.02	0.79	0.19	0.032
Skinfolds				
Pectoral	0.46	<0.0001	0.36	<0.0001
Axilla	0.44	<0.0001	0.43	<0.0001
Triceps	0.34	<0.0001	0.23	0.0105
Subscapular	0.37	<0.0001	0.26	0.0028
Abdominal	0.41	<0.0001	0.37	<0.0001
Suprailiacal	0.36	<0.0001	0.32	0.0003
Thigh	0.31	<0.0001	0.34	<0.0001
Calf	0.24	0.0014	0.42	<0.0001
Sum	0.45	<0.0001	0.43	<0.0001
Percent body fat	0.47	<0.0001	0.46	<0.0001
Skeletal muscle mass	−0.04	0.57	0.04	0.67
Weekly running hours	−0.15	0.05	−0.20	0.027
Weekly running kilometres	−0.48	<0.0001	−0.30	0.0007
Speed in running training	−0.31	<0.0001	−0.61	<0.0001

Table III. Associations between significant characteristics after bi-variate analysis and race time for the 100-km ultra-marathoners ($n = 166$) using multiple linear regression analysis. The coefficient of determination (r^2) of the model was 0.40.

Variables	Unstandardised coefficients		Standardised coefficients		
	B	**SE**	**ß**	**t**	***P***
Age	3.208	0.886	0.244	3.622	<0.0001
Body mass	3.615	1.411	0.273	2.562	0.011
Body mass index	−6.325	6.428	−0.108	−0.984	0.327
Percent body fat	5.574	2.349	0.191	2.372	0.019
Weekly running kilometres	−1.820	0.299	−0.405	−0.608	<0.0001
Speed in running training	−5.664	3.636	−0.102	−1.558	0.121

$r = 0.649$, $r^2 = 0.421$, adjusted $r^2 = 0.399$, Standard error of estimate = 96.32, $F_6 = 19.599$, $P < 0.0001$.

Table IV. Associations between significant characteristics after bivariate analysis and race time for the marathoners ($n = 126$) using multiple linear regression analysis. The coefficient of determination (r^2) of the model was 0.44.

Variables	Unstandardised coefficients		Standardised coefficients		
	B	**SE**	**ß**	**t**	***P***
Body mass index	0.214	1.116	0.015	0.192	0.848
Percent body fat	2.251	0.718	0.252	3.137	0.002
Weekly running kilometres	−0.092	0.092	−0.071	−0.991	0.323
Speed in running training	−11.936	1.707	−0.513	−6.994	<0.0001

$r = 0.676$, $r^2 = 0.457$, adjusted $r^2 = 0.439$, Standard error of estimate = 23.713, $F_4 = 25.470$, $P < 0.0001$

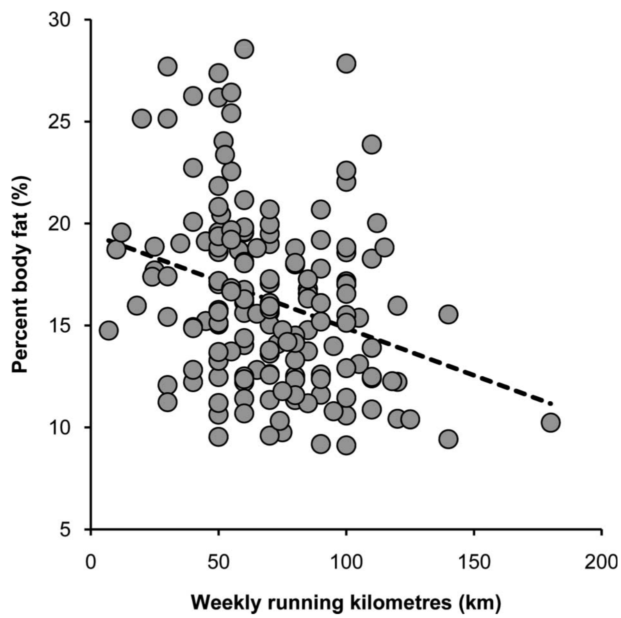

Figure 1. In the 100-km ultra-marathoners ($n = 166$), weekly running kilometres were significantly and negatively related to percent body fat ($r = -0.30$, $P < 0.0001$).

body fat and speed in running training (Table IV) were associated with marathon race times, but not age. For the 100-km ultra-marathoners, weekly running kilometres were moderately negatively associated with percent body fat (Figure 1) For the marathoners, running speed during training sessions was related moderately negatively to percent body fat (Figure 2).

Discussion

The aim of the present study was to investigate whether 100-km ultra-marathoners and marathoners were similar regarding anthropometry and training. Our hypothesis was that the two groups of athletes would show no significant differences in their training parameters or in their anthropometric measures. These two groups of athletes showed only minor differences in the circumference of calf and the skinfold thicknesses at pectoral, axilla and suprailiacal sites. However, regarding training, the

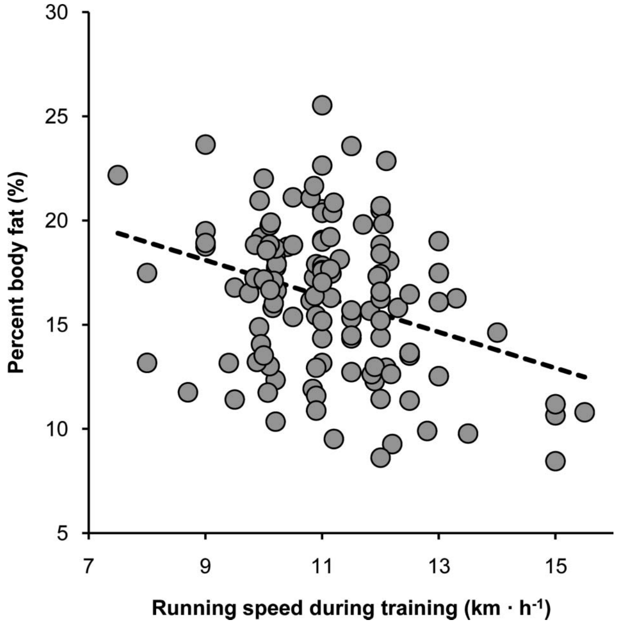

Figure 2. In the marathoners ($n = 126$), speed during running training was significantly and negatively related to percent body fat ($r = -0.32$, $P = 0.0002$).

marathoners invested significantly less time but were running significantly faster during training when compared to the 100-km ultra-marathoners.

An important finding was that percentage of body fat was related to performance in both the marathoners and the 100-km ultra-marathoners. Low body fat has previously been reported as a predictor variable for a fast race time in Ironman triathletes (Knechtle et al., 2010e; Knechtle, Knechtle, & Rosemann, 2011g) and ultra-endurance cyclists (Knechtle, Wirth, Knechtle, & Rosemann, 2009c). Regarding the training variables, running speed during training sessions was strongly negatively associated with marathon race time in the marathoners whereas weekly running kilometres were strongly negatively associated with 100-km race times in the ultra-marathoners. During training, the marathoners spent significantly less time and completed fewer kilometres compared to the 100-km ultra-marathoners, but they were running significantly faster during training. These findings are in accordance with findings from comparisons between Ironman triathletes and Triple Iron ultra-triathletes (Knechtle, Knechtle, Rüst, & Rosemann, 2011e). Both, Ironman triathletes and Triple Iron ultra-triathletes took benefit from low body fat. Furthermore, the Triple Iron ultra-triathletes invested more on training volume in cycling and running whereas the Ironman triathletes relied more on speed in cycling training (Knechtle et al., 2011e). Endurance athletes of shorter endurance races such as a marathon or an Ironman triathlon seem to base their training more on intensity whereas ultra-endurance athletes such as 100-km ultra-marathoners and Triple Iron ultra-triathletes rather focus on high volume in training (Knechtle et al., 2011e).

The previously published comparison of Ironman triathletes and Triple Iron ultra-triathletes showed other similarities with the present comparison of marathoners and 100-km ultra-marathoners (Knechtle et al., 2011e). The marathoners in our study completed the marathon within ~32% of the race time of the ultra-marathoners. The Ironman triathletes in the previous study finished the Ironman race within ~25% of the race time of a Triple Iron ultra-triathlon. Regarding performance, the marathoners in our study completed 42% of the performance of the 100-km ultra-marathoners within ~32% of the time. Expressed in other terms, this is 42% performance in 32% of the time = 42/32 or ~1.31 times the performance of the ultra-marathoners. The marathoners showed a ~1.31 times higher performance compared to the ultra-marathoners. In the previously studied Ironman triathletes, the athletes completed 33% of the performance within ~25% of the time = ~1.32 times the performance. The marathoners accounted for ~131% of the performance of the ultra-marathoners. The Ironman-triathletes achieved ~132% of the performance of the Triple Iron ultra-triathletes (Knechtle et al., 2011e). This finding suggests that the step from a marathon to a 100-km ultra-marathon is very similar to the step from an Ironman triathlon to a Triple Iron ultra-triathlon regarding the percent performance. This may explain the similarity of findings regarding volume and speed in training.

In the present study, body fat correlated moderately negatively to training volume in the 100-km ultra-marathoners and moderately negatively to running speed in the marathoners. Since correlation analysis does not prove cause and effect, low body fat is not necessarily due to training in these athletes. Low body fat in endurance athletes can also be the result of a diet (Rodriguez, Di Marco, & Langley, 2009). However, Legaz and Eston (2005) observed that training resulted in a significant increase in performance and a significant decrease in the sum of six skinfolds, abdominal, front thigh, and medial calf skinfolds in top class runners.

For both the marathoners and the 100-km ultra-marathoners in the present study, percent body fat and a number of variables of training were related to race time. However, in the 100-km ultra-marathoners, age was also highly significantly and positively related to race time in the multi-variate analysis even though age was not different between the two groups. The present results also suggest that age seems to be an important predictor variable for ultra-marathoners. Ultra-runners are able to achieve peak performance considerably later in life (Knechtle et al., 2011b) compared to marathoners (Leyk et al., 2007). In male 100-km ultra-marathoners, the best 100-km running times were achieved between the ages of 30 and 49 years (Knechtle et al., 2011b). In contrast, in male marathoners, performance started to decrease after the age of 35 years (Leyk et al., 2007). Although in the present study, participants' age was not different between the two groups of runners; the 100-km ultra-marathoners had completed significantly more marathons than the marathoners and reported a significantly faster personal best marathon time than the marathoners. This may suggest that the ultra-marathoners devoted themselves more to running than the marathoners did.

We assume that ultra-marathoners are a highly selected subgroup in runners, most probably with psychological factors which distinguish them from others. Krouse, Ransdell, Lucas, and Pritchard (2011) described female ultra-runners as task oriented, internally motivated, healthy, and financially conscious individuals. Hoffman and Fogard (2012) described male ultra-marathoners as largely well-educated, middle-aged, married men who rarely miss work due to illness or injury, generally use vitamins and/or supplements, and maintain appropriate body mass with aging. The present ultra-marathoners seem to have a longer experience and due to this experience, they probably changed their training to higher volume and lower speed. Otherwise, people who train for a longer distance will train longer distances, and by so doing they will have to slow down their training speed.

In the present ultra-marathoners, 97% had already completed a marathon, but only 73% of the marathoners had already finished a marathon. The personal best marathon time was 9 min ($\sim$4%) faster in the ultra-marathoners compared to the marathoners. The ultra-marathoners invested 3.3 hours ($\sim$41%) more in weekly training, completed 25.8 running kilometres ($\sim$37%) more but were running 0.8 $km \cdot h^{-1}$ ($\sim$7%) slower during training sessions than the marathoners. Also, the higher running volume and the lower speed in running during training might be protective against overuse injuries of the lower limbs. It has been suggested that runners exhibiting relatively large and rapid impact forces while running are at an increased risk of developing overuse injuries of the lower extremity (Hreljac, 2004). The experience of a runner may help to prevent overuse injuries. Although runners with more than 10 years running experience had an increased risk for Achilles tendinopathy (Knobloch, Yoon, & Vogt, 2008), another study showed that being active for less than 8.5 years was positively associated with injury for tibial stress syndrome (Taunton et al., 2002).

Limitations

This study has a number of limitations. First of all, we did not include general weather conditions for the events. Both, marathon (Ely, Cheuvront, Roberts, & Montain, 2007; Trapasso & Cooper, 1989; Vihma, 2010) and ultra-marathon (Parise & Hoffman, 2011; Wegelin & Hoffman, 2011) performance can be influenced by environmental temperatures. Moreover, nutrition (Maughan & Shirreffs, 2011) and fluid intake (Von Duvillard, Arciero, Tietjen-Smith, & Alford, 2008) may affect endurance performance. The anthropometric characteristics were not all measured following the protocol of the International Society for the Advancement of Kinanthropometry (ISAK), which may limit comparisons of the present results with findings from other studies. We used the mean of the skinfold measurement instead of the median. Furthermore, readings of skinfold measurement were performed 4 seconds after applying the calliper following Becque, Katch, and Moffat (1986) in contrast to ISAK where readings were performed after 2 seconds (www.isakonline.com). The use of 4 seconds to allow the calliper to compress the skinfolds limits the ability to compare with other studies, as a longer compression will lead to a smaller skinfold and hence under-predicting adiposity relative to other studies which have used 2 seconds.

Clinical significance and practical applications

For the anthropometric characteristics, the circumference of calf was 0.7 cm ($\sim$2%) larger in the ultra-marathoners, the pectoral skinfold was 0.4 mm ($\sim$9%), the axillar skinfold 0.4 mm ($\sim$4%), and the suprailiacal skinfold was 1.6 mm ($\sim$9%) thinner than in the marathoners. These differences in anthropometry are most probably negligible in contrast to the differences in training. Considering the strength of the correlations of the anthropometric characteristics in the bi-variate analysis, the skinfold thicknesses all showed a weak to moderate association with race time with the exception of pectoral, axillar and abdominal skinfold for ultra-marathoners and the axillar and calf skinfold for marathoners. These skinfold thicknesses showed a strong positive relationship with race time. However, percentage of body fat showed, for both ultra-marathoners and marathoners, a strong positive relationship with race time.

Regarding the training variables, speed of running during training showed a strong positive relationship with marathon race time and weekly running kilometres was strongly positively associated with ultra-marathon race times. Training variables seem to be of equal importance compared to body fat for both ultra-marathoners and marathoners with the difference that weekly running kilometres was a strong and positive variable in ultra-marathoners and speed during running training strongly positively related to marathon race time in the marathoners.

Conclusions

To summarise, 100-km ultra-marathoners and marathoners showed some minor differences in anthropometric characteristics including a significant difference in the circumferences of calf and a significant difference in the skinfold thicknesses at pectoral, axilla and suprailiacal sites.

Our results also support previous research suggesting that running athletes benefit from low body fat. Finally, our results suggest that ultra-marathoners relied more on high volume during training whereas marathoners focus more on high running speed.

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