ORIGINAL RESEARCH

Comparison of anthropometric and training characteristics between recreational male marathoners and 24-hour ultramarathoners

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Background: Of the anthropometry and training variables used to predict race performance in a 24-hour ultrarun, the personal best marathon time is the strongest predictor in recreational male 24-hour ultramarathoners. This finding raises the question of whether similarities exist between male recreational 24-hour ultramarathoners and male recreational marathoners.

Methods: The association between age, anthropometric variables (ie, body mass, body height, body mass index, percent body fat, skeletal muscle mass, limb circumference, and skinfold thickness at the pectoral, mid axillary, triceps, subscapular, abdominal, suprailiac, front thigh, and medial calf sites), previous experience and training characteristics (ie, volume, speed, and personal best time), and race time for 79 male recreational 24-hour ultramarathoners and 126 male recreational marathoners was investigated using bivariate and multivariate analysis.

Results: The 24-hour ultramarathoners were older ($P < 0.05$), had a lower circumference at both the upper arm ($P < 0.05$) and thigh ($P < 0.01$), and a lower skinfold thickness at the pectoral, axillary, and suprailiac sites ($P < 0.05$) compared with the marathoners. During training, the 24-hour ultramarathoners were running for more hours per week ($P < 0.001$) and completed more kilometers ($P < 0.001$), but were running slower ($P < 0.01$) compared with the marathoners. In the 24-hour ultramarathoners, neither anthropometric nor training variables were associated with kilometers completed in the race ($P > 0.05$). In the marathoners, percent body fat ($P < 0.001$) and running speed during training ($P < 0.0001$) were related to marathon race times.

Conclusion: In summary, differences in anthropometric and training predictor variables do exist between male recreational 24-hour ultramarathoners and male recreational marathoners for race performance.

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

Introduction

Ultramarathon running is very popular.[1–4] Recent studies have shown an increase in participation in 161 km ultramarathons in recent years, in which master athletes have shown the greatest increases in participation.[1–3] Several studies have attempted to define predictor variables for ultramarathon performance.[5–15] Variables in physiology (eg, maximum oxygen uptake),[14,15] anthropometry (eg, skinfold thickness, percent body fat),[8,11,13] previous experience (eg, personal best times),[6,9–12] and training (eg, running speed during training)[8–12] seem to have an influence on race outcome in ultramarathoners. In addition, age seems to affect ultramarathon performance.[8,16] Different types of races exist in ultramarathon running. Athletes can participate in single-stage[17] or multistage[18] races, in which they have to cover a given distance in the shortest possible time. However, other ultramarathons exist where the participants have to complete the longest distance

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possible within a given time. These are 6-hour, 12-hour, 24-hour, 48-hour, and 72-hour ultramarathons.[19]

Amongst the variables in both anthropometry and training predictive of race performance in a 24-hour ultramarathon, personal best marathon time has been reported to be a strong predictive variable for male recreational 24-hour ultramarathoners.[5,12] This finding raises the question of whether similarities exist between male recreational 24-hour ultramarathoners and male recreational marathoners. For runners up to the marathon distance, different variables have been shown to correlate with running performance. Regarding physiological variables, the lactate value at both 10 km/hour and 22 km/hour running speeds[20] and maximum oxygen uptake[21] were associated with running performance. For anthropometric characteristics, body mass[22,23] and lower limb skinfold thickness[24,25] correlated with running performance. Considering training variables, the number of previously completed marathons,[22] number of daily workouts,[21,22] number of training runs of long duration,[21] mean running distance per week,[21] mean number of kilometers run per day,[21] longest running distance covered per training session,[26] duration of training,[22] kilometers run per week,[22,36] and running speed during training[22,27] have been associated with running performance.

A recent study comparing 100 km ultramarathoners and marathoners showed that age, body mass, and percent body fat were positively related and kilometers run per week were negatively related to 100 km race times in ultramarathoners.[28] However, in the marathoners, percent body fat was positively associated and speed in running training was negatively associated with marathon race times. Because both anthropometric and training variables were related to race performance in both 100 km ultramarathoners and marathoners,[28] we investigated whether male recreational 24-hour ultramarathoners and male recreational marathoners were similar regarding their anthropometry and training. In a 24-hour ultramarathon, athletes achieve distances of approximately 150 km.[12,13] Our hypotheses were, firstly, that the two groups of athletes would show no significant differences in either their training parameters or anthropometric measurements and, secondly, that anthropometric characteristics, such as body fat, and training characteristics, including running speed during training, would be related to performance in both groups of athletes.

Materials and methods
Subjects
All male ultramarathoners in the 24-hour Basel ultramarathon and all male runners in the Basel marathon in

Switzerland were informed about the planned investigation via an electronic newsletter sent by the organizer 3 months before the start of the race. We focused on recreational male athletes, defined as athletes pursuing a regular occupation, performing sport during leisure time, having no sponsors, and not earning their livelihood through sponsorship or prize money. A total of 79 subjects were recruited for the 24-hour Basel ultramarathon, where athletes were recruited in two consecutive years from 2010 to 2011. For the Basel marathon, a total of 126 male marathoners were investigated prerace. The study was approved by the institutional review board for use of human subjects at the Canton of St Gallen, Switzerland. The athletes were informed of the experimental procedures and gave their informed written consent to participate. No athlete was included twice and no athlete competed in both races.

Races
The 24-hour Basel ultramarathon takes place every year in mid May. Ultramarathoners from all over Europe start at noon, and perform as many laps as possible on a flat course over 24 hours to achieve the longest distance possible. Each lap of 1.141 km is counted by a personal lap counter for each runner. The 24-hour ultramarathoners had the opportunity to consume food and beverages ad libitum from an abundant buffet provided by the organizer. If preferred, they could also ingest food provided by their personal support crews. The support crews were also allowed to help with changing clothes and shoes. In the Basel marathon, the athletes had to run two laps on asphalt at an altitude of 200 m. The organizer offered food and fluids at aid stations. Because the participation rate in an ultramarathon race is low,[1–4,29] data were collected from the 24-hour Basel ultramarathon during four consecutive years (2008–2011), to increase the sample size for 24-hour ultramarathoners.

Anthropometric measurements
The afternoon before the start of the race, anthropometric characteristics such as body mass, body height, limb circumference, and skinfold thickness at the pectoral, mid axillary, triceps, subscapular, abdominal, suprailiac, front thigh, and medial calf sites were measured. Limb circumference and skinfold thickness were measured on the right side of the body. Using these data, body mass index, percent body fat, and skeletal muscle mass were calculated by anthropometric methods. 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 to

the nearest 0.01 m (Tanita HR 001 portable height measure, Tanita Europe, Amsterdam, The Netherlands). Limb circumference was measured using a nonelastic tape measure (KaWe CE, Kirchner und Wilhelm, Aspberg, Germany) to the nearest 0.1 cm. The circumference of the upper arm was measured at the mid arm, the circumference of the thigh was taken at the mid thigh, and the circumference of the calf was measured at the mid calf. All skinfold data were obtained using a skin-fold caliper (GPM-Hautfaltenmessgerät, Siber and Hegner, Zurich, Switzerland) and recorded to the nearest 0.2 mm. The skin-fold caliper measures with a pressure of 0.1 MPa ±5% over the whole measuring range. The skinfold measurements were taken once for all eight skinfold sites, and the procedure was then repeated twice more by the same investigator, and the mean of three measurements was used for the analyses. The timing of skinfold measurement was standardized to ensure reliability. According to the method reported by Becque et al, readings were performed 4 seconds after applying the caliper.[30] One trained investigator took all skinfold measurements because intertester variability is a major source of error in skinfold measurements. Intrarater and interrater agreement was assessed in 27 male runners prior to an ultramarathon, based on measurements taken by two experienced primary care physicians.[31] The intraclass correlation (ICC) within the two raters was excellent for all anatomical sites measured and for various summary measurements of skinfold thicknesses (ICC > 0.9). Agreement tended to be higher within than between raters, but still showed excellent reliability (ICC > 0.9) for the summary measurements of skinfold thickness. For the sum of eight skinfolds for measurer 1, bias (average difference between measure 1 and 2) was −0.515 mm, the standard deviation of the average difference was 1.492 mm, and the 95% limits of agreement were between −3.439 mm and 2.409 mm.

Estimation of body fat and skeletal muscle mass

Percent body fat was estimated using the anthropometric formula devised by Ball et al for males where percent body fat $= 0.465 + 0.180 \times (\Sigma7SF) - 0.0002406 \times (\Sigma7SF)^2 + 0.0661 \times$ (age), where $\Sigma7SF$ is the sum of skinfold thickness for the pectoralis, axillary, triceps, subscapular, abdomen, suprailiac, and thigh sites (mean in mm, age in years).[32] The predicted residual sum of squares (PRESS) r^2 was high (0.90) and the PRESS standard error of estimates was excellent (2.2% of 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, with SMM $=$ Ht $\times (0.00744 \times CAG^2 + 0.00088 \times CTG^2 + 0.00441 \times CCG^2) + 2.4 \times$ gender $- 0.048 \times$ age $+$ race $+ 7.8$, where Ht is height, CAG is skinfold-corrected upper arm girth, CTG is skinfold-corrected thigh girth, CCG is skinfold-corrected calf girth, gender $= 1$ for male (age is in years, and race $= 0$ for white men and 1 for black men).[33] 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 skeletal muscle mass measured by MRI ($r^2 = 0.83$, $P < 0.0001$, standard error of estimates $= 2.9$ kg). The correlation between the measured and predicted skeletal muscle mass difference and the measured skeletal muscle mass was significant ($r^2 = 0.90$, $P = 0.009$).

Training records

Upon recruitment into the study 3 months before the start of both the 24-hour Basel ultramarathon and the Basel marathon, the subjects were asked to record their training units, showing duration in minutes and distance in kilometers, until the start of the race. The investigator provided an electronic file in which the subjects could insert each training unit with distance, duration, and speed, expressed in km/hour. The investigator then calculated the mean weekly hours, mean weekly kilometers run, and the mean speed per discipline during training in the prerace preparation. In addition, the subjects reported their personal best marathon time, defined as the fastest marathon race time ever achieved beforehand, independent of the race course and environmental conditions. Twelve marathoners and six 24-hour ultramarathoners dropped out in the time interval between recruitment and the race day. The athletes and the researcher were in email contact between recruitment and race day.

Statistical analysis

The data were analyzed using SPSS software version 15 (SPSS Inc, Chicago, IL). The data were checked for distribution of normality and are presented as the mean ± standard deviation. The coefficient of variation (CV) of performance (CV% $= 100 \times$ standard deviation/mean) was calculated. The CV describes the magnitude of the sample values and the variation within them. Data for the 24-hour ultramarathoners and marathoners were compared using the Mann-Whitney U test. An alpha level of 0.05 was used to indicate a statistically significant difference. To investigate a potential association between anthropometric and training characteristics and

race performance, as a first step, the relationship between marathon race time for the marathoners and the kilometers completed for the 24-hour ultramarathoners as the dependent variable and the variables of age, anthropometry, training, and previous experience was investigated using bivariate Pearson correlation analysis. In order to reduce the variables in the multivariate analysis, Bonferroni correction was applied ($P < 0.0023$ for 22 variables). In a second step, all variables identified as significant after bivariate analysis were entered into a multiple linear regression analysis (stepwise, forward selection, P of F for inclusion < 0.05, P of F for exclusion > 0.1). Multicollinearity between the predictor variables was excluded with $r > 0.9$. A power calculation was performed according to the method reported by Gatsonis and Sampson.[34] A sample of 40 participants was required to achieve a power of 80% (two-sided type I error of 5%) and detect a minimal association between race time and anthropometric characteristics of 20% (ie, coefficient of determination $r^2 = 0.2$).

Results

Of the 126 marathoners, 92 (73%) had already completed at least one marathon (mean 12 ± 22 marathons). Their personal best marathon time was 216 ± 32 minutes. For the 79 24-hour ultramarathoners, 74 (98%) had already finished a marathon (mean 26 ± 23 marathons) with a mean personal best marathon time of 198 ± 31 minutes. The 24-hour ultramarathoners had completed significantly more marathons prerace ($P < 0.0001$); however, their personal best marathon time was not faster compared with the marathoners ($P > 0.05$).

Performance of 24-hour ultramarathoners and marathoners

The 24-hour ultramarathoners ran a distance of 144 ± 43 kilometers within the 24 hours, with a CV of performance of 29.5%. Expressed as a percentage of the course record of 290.225 km set by Yannis Kouros in 1998, they achieved $49.8\% \pm 15.0\%$ of the record. While racing, they were running at a mean speed of 6.0 ± 1.8 km/hour. The marathoners finished their marathon within 231 ± 31 minutes (CV 13.7%), which is equal to approximately 3 hours 51 minutes. The mean performance of the marathoners represents 68.4% of the best performance of 2 hours 38 minutes set by Andreas Schur in 2010. The marathoners were running at a speed of 11.1 ± 1.4 km/hour in the marathon, which was significantly faster than the 24-hour ultramarathoners in their 24-hour ultramarathon ($P < 0.0001$).

Differences between 24-hour ultramarathoners and marathoners

The 24-hour ultramarathoners were older, had smaller upper arm and thigh circumferences and lower skinfold thickness at the pectoral, axillary, and suprailiac sites compared with the marathoners (Table 1). During training, the 24-hour ultramarathoners were running for more hours per week and completed more kilometers, but were running slower

Table 1 Comparison of anthropometry and training between 24-hour ultramarathoners and marathoners

	24-hour ultramarathoners (n = 79)	Marathoners (n = 126)	Difference
Age (years)	47.0 ± 10.5	42.8 ± 10.8	$P < 0.05$
Body mass (kg)	72.8 ± 7.6	73.9 ± 8.0	
Body height (m)	1.77 ± 0.07	1.78 ± 0.06	
Body mass index (kg/m²)	23.0 ± 1.7	23.4 ± 2.2	
Circumference of upper arm (cm)	28.4 ± 1.7	29.2 ± 1.9	$P < 0.05$
Circumference of thigh (cm)	53.3 ± 3.3	54.9 ± 2.6	$P < 0.01$
Circumference of calf (cm)	37.9 ± 2.2	37.9 ± 2.3	
Skinfold pectoral (mm)	7.1 ± 3.2	8.1 ± 3.0	$P < 0.05$
Skinfold axillary (mm)	8.6 ± 3.3	9.6 ± 2.8	$P < 0.05$
Skinfold triceps (mm)	7.9 ± 2.5	7.8 ± 2.6	
Skinfold subscapular (mm)	10.5 ± 4.2	10.5 ± 4.0	
Skinfold abdominal (mm)	16.5 ± 7.9	15.4 ± 6.3	
Skinfold iliac (mm)	15.7 ± 8.2	18.3 ± 7.1	$P < 0.05$
Skinfold thigh (mm)	12.5 ± 7.4	12.0 ± 5.0	
Skinfold calf (mm)	6.4 ± 2.7	6.1 ± 2.4	
Sum of skinfolds (mm)	85.1 ± 32.0	87.4 ± 27.2	
Percent body fat (%)	16.0 ± 4.2	16.2 ± 3.7	
Skeletal muscle mass (kg)	37.0 ± 3.8	38.1 ± 3.9	
Years as runner	13.5 ± 8.8	10.5 ± 9.4	$P < 0.05$
Weekly running hours	9.1 ± 5.0	4.8 ± 2.5	$P < 0.001$
Weekly running kilometers	86.5 ± 35.9	44.7 ± 24.7	$P < 0.001$
Speed in running training (km/hour)	10.2 ± 1.5	11.0 ± 1.4	$P < 0.01$

Note: Results are presented as the mean ± standard deviation.

than the marathoners. In the 24-hour ultramarathoners, no anthropometric or training variables were associated with kilometers completed in the 24-hour ultramarathon after bivariate analysis (Table 2). For the marathoners, percent body fat and running speed during training were related to marathon race time in the multivariate analysis (Table 3). Running speed during training sessions was significantly and negatively correlated with percent body fat in the marathoners (Figure 1).

Due to the fact that the CV of performance was very high in the 24-hour ultramarathoners compared with the marathoners and neither anthropometric nor training variables were related to kilometers run over 24 hours, we performed a separate multivariate regression analysis including only the 24-hour ultramarathoners who had completed at least 100 km (CV 21.9%) and 150 km (CV 14.5%). No anthropometric or training variables were related to kilometers run over 24 hours in the 65 24-hour ultramarathoners who

Table 2 Association of anthropometric and training characteristics with race time for both the 24-hour ultramarathoners and the marathoners using bivariate analysis

	24-hour ultramarathoners (n = 79)		Marathoners (n = 126)	
	r	P	r	P
Age	0.02	0.8	0.23	0.0096
Body mass	−0.25	0.03	0.24	0.0069
Body height	−0.17	0.1	−0.01	0.95
Body mass index	−0.17	0.1	0.27	0.0019
Circumference of upper arm	−0.03	0.8	0.16	0.067
Circumference of thigh	−0.09	0.4	0.23	0.0088
Circumference of calf	−0.10	0.4	0.19	0.032
Skinfold pectoral	−0.23	0.04	0.36	<0.0001
Skinfold axillary	−0.30	0.006	0.43	<0.0001
Skinfold triceps	−0.21	0.06	0.23	0.0105
Skinfold subscapular	−0.23	0.04	0.26	0.0028
Skinfold abdominal	−0.28	0.01	0.37	<0.0001
Skinfold suprailiac	−0.26	0.02	0.32	0.0003
Skinfold thigh	−0.15	0.2	0.34	<0.0001
Skinfold calf	−0.05	0.6	0.42	<0.0001
Sum of skinfolds	−0.28	0.01	0.43	<0.0001
Percent body fat	−0.28	0.01	0.46	<0.0001
Skeletal muscle mass	−0.07	0.5	0.04	0.67
Years as runner	0.03	0.8	−0.08	0.3
Weekly running hours	0.13	0.3	−0.20	0.027
Weekly running kilometers	0.15	0.2	−0.30	0.0007
Speed in running training	0.27	0.01	−0.61	<0.0001

Note: Variables with P values of <0.0023 are inserted in the multivariate analysis (n = 22 variables).

Table 3 Associations between significant characteristics after bivariate analysis and race time for marathoners using multiple linear regression (n = 126)

|	β	SE	P
Marathoners			
Body mass index	0.6	1.0	0.5
Percent body fat	2.4	0.6	0.0002
Kilometers run weekly	−0.1	0.1	0.2
Speed in running training	−11.5	1.7	<0.0001
24-hour ultramarathoners (>100 km)			
Body mass index	−3.8	3.1	0.2
Percent body fat	1.1	1.9	0.6
Kilometers run weekly	0.3	0.1	0.07
Speed in running training	4.9	4.7	0.3
24-hour ultramarathoners (>150 km)			
Body mass index	−2.1	2.7	0.4
Percent body fat	−2.2	1.3	0.08
Kilometers run weekly	0.06	0.1	0.6
Speed in running training	2.7	2.9	0.3

Notes: The coefficient of determination (r^2) for the model was 0.47. The same variables were used for the 24-hour ultramarathoners achieving more than 100 km within 24 hours (n = 65) and more than 150 km (n = 35). No variable was significant in the 24-hour ultramarathoners; r^2 was 0.19 for both models.
Abbreviations: β, regression coefficient; SE, standard error of the regression coefficient.

ran more than 100 kilometers (Table 3) or in the 35 24-hour ultramarathoners completing more than 150 kilometers.

Associations between performance and age, anthropometry, and training

Age showed no association with performance in the 24-hour ultramarathoners ($r = 0.02$, $P > 0.05$) (Table 2). However, in
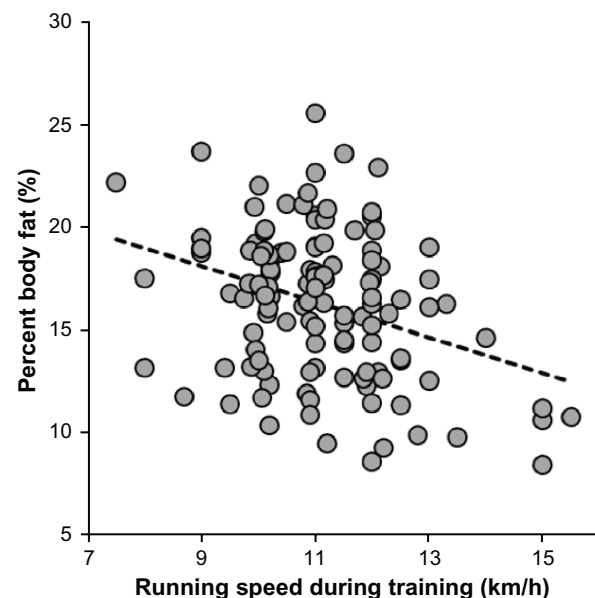
Figure 1 In the marathoners (n = 126), speed during running training was significantly and negatively related to percent body fat ($r = −0.32$, $P = 0.0002$).

the marathoners, age was significantly and positively related to marathon race times ($r = 0.23$, $P = 0.0096$). Because age, upper arm and thigh circumferences, skinfold thickness at the pectoral, axillary, and suprailiac sites, and training volume and speed were different between the 24-hour ultramarathoners and the marathoners, we investigated potential associations between these anthropometric and training variables for each group. While skinfold thickness was related to kilometers run each week and running speed during training in both the 24-hour ultramarathoners and the marathoners (Table 4), skinfold thickness was also related to weekly running hours in the marathoners. In addition, pectoral and axillary skinfold thickness was related to age in the marathoners.

Discussion

The aim of the present study was to compare age, anthropometric, and training characteristics between male recreational 24-hour ultramarathoners and male recreational marathoners. The primary outcome was that these two groups of athletes showed differences in age, upper arm and thigh circumference, and skinfold thickness at pectoral, axillary, and suprailiac sites. However, the marathoners invested less time in training but were training faster compared with the 24-hour ultramarathoners.

Differences in anthropometry and training

An important finding was that no anthropometric or training variables were related to kilometers run by the 24-hour ultramarathoners. This is in contrast with the marathoners, in whom percent body fat and running speed during training was associated with marathon race time. The present findings

are also in contrast with those of a recent study comparing 100 km ultramarathoners and marathoners which showed that age, body mass, and percent body fat were positively related and kilometers run weekly were negatively related to 100 km race times in ultramarathoners.[28] However, in marathoners, percent body fat was positively associated and training speed was negatively associated with marathon race times.

Differences in anthropometry and training between the two groups of athletes might explain these disparate findings. In the study comparing 100 km ultramarathoners and marathoners, the marathoners had a significantly lower calf circumference and significantly thicker skinfolds at the pectoral, axillary, and suprailiac sites compared with the 100 km ultramarathoners.[28] Also, the marathoners ran for significantly fewer hours and covered significantly fewer kilometers during the week, but were running significantly faster during training.[28] However, in the present investigation, none of the variables compared between the 24-hour ultramarathoners and the marathoners was related to race performance in either group after multivariate analysis.

Another explanation could be the performance of the athletes. We calculated CV for performance in order to compare the achievements of the runners. The CV in the 24-hour ultramarathoners was 29.5%, which is considerably higher than the CV for performance of 13.7% in the marathoners. When we expressed the performance of the athletes as a percentage of the course record, the 24-hour ultramarathoners were approximately 50% below the longest distance achieved, whereas the marathoners were about 50% above the course record. Although the percentages were the same, we assume that the higher CV for the performance of 24-hour ultramarathoners compared with marathoners

Table 4 Association of anthropometric characteristics with age and training variables in 24-hour ultramarathoners (n = 79) and in marathoners (n = 126)

	Age	Year as active runner	Kilometers run weekly	Weekly hours run	Running speed during training
24-hour ultramarathoners					
Circumference of upper arm	$r = -0.16$	$r = 0.00$	$r = -0.08$	$r = 0.01$	$r = -0.03$
Circumference of thigh	$r = -0.18$	$r = -0.08$	$r = -0.12$	$r = 0.08$	$r = -0.07$
Pectoral skinfold	$r = 0.19$	$r = 0.00$	$r = -0.27$, $P = 0.01$	$r = -0.01$	$r = -0.51$, $P < 0.0001$
Axillary skinfold	$r = -0.05$	$r = 0.02$	$r = -0.29$, $P = 0.009$	$r = -0.05$	$r = -0.45$, $P < 0.0001$
Suprailiac skinfold	$r = -0.08$	$r = 0.00$	$r = -0.30$, $P = 0.007$	$r = -0.16$	$r = -0.31$, $P = 0.005$
Marathoners					
Circumference of upper arm	$r = -0.06$	$r = 0.13$	$r = 0.01$	$r = -0.06$	$r = -0.01$
Circumference of thigh	$r = -0.05$	$r = 0.11$	$r = 0.05$	$r = -0.07$	$r = -0.03$
Pectoral skinfold	$r = 0.27$, $P = 0.002$	$r = 0.08$	$r = -0.23$, $P = 0.01$	$r = -0.19$, $P = 0.03$	$r = -0.24$, $P = 0.007$
Axillary skinfold	$r = 0.23$, $P = 0.01$	$r = 0.09$	$r = -0.27$, $P = 0.002$	$r = -0.21$, $P = 0.02$	$r = -0.23$, $P = 0.01$
Suprailiac skinfold	$r = -0.01$	$r = 0.01$	$r = -0.30$, $P = 0.0006$	$r = -0.18$, $P = 0.04$	$r = -0.25$, $P = 0.005$

Note: *R* values represent Pearson correlation coefficients. *P* values are provided in the event of a significant association.

was the reason that none of the anthropometric or training variables were related to race performance in the 24-hour ultramarathon.

In a 24-hour ultramarathon, the runners do not have to finish a defined distance within a time limit, which is generally the opposite of what is expected in an endurance performance, and instead have to cover the greatest possible distance within 24 hours. Therefore, the athletes can run more slowly or as fast as possible and take breaks or go to sleep when they want. If an athlete suffers from an overuse injury or has another medical problem, such as dehydration or a digestive problem, the athlete can stop, solve the problem, and continue the race. When an athlete stops running before the 24 hours are over, the kilometers completed are considered to be that athlete's race performance and the athlete is ranked in the final race results. This may explain the large CV for performance of 29.5% in the present 24-hour ultramarathoners. The large CV in performance and the rather weak performance of about 145 km, varying from 63 km to 238 km over 24 hours, compared with the 199 km in the study of Kao et al[4] with distances between 127 km and 261 km, might also be an indicator of motivational problems.[7]

When we investigated body mass index, body fat, kilometers run per week, and running speed during training as potentially predictive variables for 24-hour ultramarathoners completing more than 100 kilometers or more than 150 kilometers, none of the anthropometric or training variables was related to the kilometers achieved over the 24 hours. Although the CV for performance dropped, the CV in the multivariate regression model did not change. We assume that other predictive variables, such as personal best marathon time and differences in running economy[35] are more important than anthropometric characteristics and training in a 24-hour race.[5,12] Another explanation may be that the CV differed according to the type of test (ie, a constant duration test, constant distance test, or constant velocity test) as discussed by Coquart and Garcin.[36] During a marathon, the athletes take no breaks, whereas during a 24-hour ultramarathon, athletes may make breaks to change clothes and to eat. Indeed, the constant duration test reported a low CV of about 3%[37] in comparison with constant velocity tests, with the CV between 5.2% and 55.9%,[38] whereas a CV in the constant distance test is approximately 2%.

A further potential explanation for these differences might be the difference in age. The marathoners were younger than the 24-hour ultramarathoners. In 100 km ultramarathoners, running speed during training, training volume, and age have been shown to predict race time.[8] However, in marathoners, percent body fat and running speed but not age were predictive.[39] In addition, the weather during the 24-hour ultramarathon with temperatures changing between day and night might have had an important influence.[40]

Associations between anthropometric characteristics and training

A further finding was the difference in skinfold thickness between the two groups of athletes, indicating different relationships with training characteristics. Skinfold thickness at the pectoral, axillary, and suprailiac sites was related to both kilometers run per week and running speed during training in both the 24-hour ultramarathoners and the marathoners, and skinfold thickness at the same sites was also related to hours run per week in the marathoners.

Legaz and Eston[41] showed that training resulted in a significant increase in performance and a significant decrease in the sum of six abdominal, front thigh, and medial calf skinfold thicknesses in top class runners. Correlation analysis does not demonstrate cause and effect, so low skinfold thickness is not necessarily due to training. Low skinfold thickness and low body fat in endurance athletes can also be the result of diet.[42]

Limitations and practical applications

This study has some limitations. We did not include general weather conditions because both marathon[43–45] and ultramarathon[40,46] performance can be influenced by environmental temperature. Also, nutrition[47] and fluid intake[48] may affect ultraendurance performance, and inclusion of physiological variables[49] might be important in predicting running performance. Self-reporting of times and distances during training was a limitation because we had no way of establishing the reliability and precision of reporting. For future research, the reliability of training data might be enhanced by quantifying and validating self-reported training data using a global positioning system. Based on the present findings, recreational marathoners and 24-hour ultramarathoners are not comparable regarding their anthropometry and training. However, any runner aiming to achieve needs to have broad experience in running, invest about 9 hours per week in running training, run at about 10 km/hour during training, and run approximately 90 kilometers per week.

Conclusion

To summarize, 24-hour ultramarathoners and marathoners showed minor differences in limb circumference and skinfold thickness, but major differences in training variables.

The largest difference found was that there was no predictive variable for 24-hour ultramarathoners. However, lower body fat and a higher running speed during training were related to a faster marathon race time in marathoners. Although personal best marathon time has been reported to be a strong predictive variable for recreational 24-hour ultramarathoners, the recreational marathoners and recreational 24-hour ultramarathoners in our study were not comparable regarding their anthropometry and training.

Disclosure

The authors declare that they have no competing interests in this work.

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