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PREDICTOR VARIABLES FOR 100 KM RACE TIME IN FEMALE ULTRA-MARATHONERS

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Abstract

Background and Aims: We investigated the association of anthropometry, pre race experience and training variables with race performance in 19 recreational female ultra-runners in a 100 km run.

Methods: Variables of anthropometry and training were correlated to race time using bi- and multivariate analysis.

Results: In the bivariate analysis, age (r = - 0.46), body mass (r = 0.55), body stature (r = 0.47), circumference of upper arm (r = 0.54), circumference of calf (r = 0.47), thickness of triceps skin-fold (r = 0.52), duration of run training sessions (r = - 0.55) and personal best marathon time (r = 0.63) were significantly related to race time. When all variables with significant bivariate association were entered into the multivariate analysis, the thickness of triceps skin-fold (*P* = 0.04) and personal best time in a marathon (*P* = 0.04) were related to race time.

Conclusions: These results indicate that triceps skin-fold thickness and personal best marathon time were related to race time, but not variables of training. Race time for female 100 km ultra-marathoners might be predicted by the following equation (n=17, r^2 = 0.52): Race time (min) = 183.1 + 7.6 x (triceps skin fold, mm) + 2.1 x (personal best marathon time, min)

Key words: *body fat, athlete, endurance, gender*

Introduction

Running is a popular sports discipline and can be performed over different distances [1, 2]. An abundant variety of physiological, anthropometrical and training variables seem to influence running performances depending upon the length and duration of the performance [3-6]. Apart from physiological parameters, several different anthropometric variables are related to endurance running performance such as body mass [7, 8], body height [9, 10], body mass index [11, 13], body fat [11], total skin-fold thickness [7], skin-fold thickness of the lower limb [14-16], length of legs [17, 18] and circumferences of limbs [13, 18-20].

These anthropometric properties have different associations regarding running distances and gender. Body height seems to be associated with performance in both male and female marathon runners [9]. Body mass index is related to marathon performance in females [11]. In ultra-running, body mass index is related to ultra-marathon performances in both males and females [12]. Body fat is positively associated with marathon performance times in females [11]. The relationship between skin-fold thicknesses and running performance has been investigated in several studies. Hagan *et al.* could demonstrate that apart from other variables, the sum of seven skin-fold thicknesses was slightly correlated with marathon performance time in males [21]. Bale *et al.* found that the total sum of skin-fold thicknesses, the type and frequency of training and the number of years running were the best predictors of running performance and success in the 10,000 m distance for males [7]. In more recent studies, a relationship between the thicknesses of selected skin-folds and running performance has been demonstrated in top class runners [14, 15]. In these studies, elite runners of distances from 100 m to 10,000 m and the marathon had been investigated [14, 15]. High correlations were found between the front thigh and medial calf skin-fold and 10,000 m race times in male runners, and between iliac crest and abdominal skin-fold and marathon time in female runners [14].

Apart from anthropometry, volume and intensity in training seem to influence running performance in long-distance runners up to the marathon distance. In marathon finishers, the longest mileage covered per training session is the best predictor for a successful completion of a marathon [22]. Scrimgeour *et al.* found that male runners training for more than 100 km per week have significantly faster race times over 10,000 m to 90 km than athletes covering less than 100 km [23]. Bale *et al.* demonstrated in 60 male runners, that elite runners with a higher training frequency, higher weekly training volume and longer running experience had a better 10,000 m performance [7]. In female marathon runners, Bale *et al.* could show that the number of weekly training sessions and the number of years training were the best predictors of competitive performance [24]. According to Hewson & Hopkins, a correlation exists between seasonal weekly duration of moderate continuous running for male and female runners specialising in longer distances [25]. Christensen and Ruhling concluded that improved marathon performance in women marathon runners is associated with higher aerobic capacity and years of training rather than with body dimensions [26]. In training, intensity in running is also of importance. According to Billat *et al.*, both male and female top class marathon runners train for more total kilometres per week and at a higher velocity than runners at a lower level [27]. Peak running velocity is highly related to 5,000 m run times for both male and female athletes [28]. When training in runners is analysed in detail, several parameters such as workout days, total workouts, total kilometres, mean kilometres per workout, longest mileage covered per training session, total training minutes, maximal kilometres of running per week, mean kilometres per week and mean kilometres per day, seem to have an effect on a marathon performance [11, 21, 22].

Anthropometric properties and their effect on exercise performance during short and middle distance running, as well as marathon running, have been investigated previously [14, 15]; however, there is very little scientific data about the effect of anthropometry on race performance in ultra-marathon running [8, 12, 19]. Ultra-running means distances longer than the classic marathon distance of 42.195 km. Ultra-marathon runners seem to have a lower body mass index compared to sedentary people [29] and have low amounts of fat on the abdomen and legs [30]. These low amounts of body fat are supposed to be the result of intense training in ultra-runners [30] and this intense training may lead to an improved performance [24]. Probably a thinner upper body with low circumferences of the upper arm is advantageous for ultra-runners of distances of more than 300 km [8] or even 1,200 km [19].

Furthermore, there is little data about a potential association of training parameters and race performance in ultra-marathoners. In addition to training volume, previous race experience might also be of importance since in a recent study of male ultra-runners a positive association of a personal best time in marathon running on performance in a 24-hour run was demonstrated, whereas anthropometry and training volume showed no relationship [31]. In ultra-running, there exist several distances of longer than the classic marathon distance of 42.195 km. A 100 km run is the first step for runners wishing to compete in ultra-running. Little is known about the association between anthropometry and training with performance in female ultra-runners. Regarding the present literature, we found one study where 54 female ultra-runners over 161 km were included [12], one study investigating 10 female ultra-runners over 90 km [32] and one case study of a female ultra-runner in a multi-stage ultra-run over 1,200 km [33]; but no field study of female 100 km ultra-endurance runners.

The aim of this present study of female 100 km runners was therefore to investigate potential associations of anthropometric and training variables with race time. Regarding the present literature on distances up to the marathon, we hypothesised finding an association between both anthropometric variables, such as skin-fold thicknesses, and training variables, such as pre race experience, with race performance.

Materials and Methods

Participants

The organiser of the 100 km run in Biel, Switzerland, contacted all female participants of the 2008 race via a separate newsletter at the time of inscription to the race, in which they were asked to participate in the study. About 400 female runners intended to start in the race; a total of 19 female ultra-runners were interested in the investigation. The athletes were informed of the procedures and gave their informed written consent. The study was approved by the Institutional Review Board for use of Human subjects of St. Gallen, Switzerland. The anthropometric and training variables of the subjects are represented in Tables 1-3. They all finished the race within the time limit.

The race

The 100 km run in Biel, Berne, Switzerland, took place during the night of 13 to 14 June 2008. The runners started on 13 June at 10:00 p.m. and had to finish the 100 km within 17 hours, with a total climb in altitude of 645 metres. Two thirds of the course was on asphalt, and one third was on unpaved roads. Throughout the 100 km there were 17 aid stations at intervals of 5 to 10 km with a variety of food and beverages. The organiser offered isotonic sports drinks, tea, soup, caffeinated drinks, water, bananas, oranges, energy bars and bread. The athletes were allowed to be supported by a cyclist in order to have additional food and clothing, if necessary. At the start the temperature was 15° Celsius. During the night, the temperature dropped to 8° Celsius and rose to 18° Celsius the next morning by 10:00 a.m.

Table 1. *Association of age and anthropometric variables with race time (n=19)*

		r
Age (years)	43.0 (37.5-52.0)	- 0.46, *P*=0.0475
Body mass (kg)	63.4 (49.8-71.8)	0.55, *P*=0.0155
Body stature (m)	1.67 (1.62-1.76)	0.47, *P* =0.0429
Body mass index (kg/m^2)	22.2 (19.6-23.3)	0.32
Length of leg (cm)	82.5 (77.2-90.9)	0.43
Circumference of upper arm (cm)	25.8 (24.5-27.7)	0.54, *P* =0.0179
Circumference of thigh (cm)	52.5 (49.5-55.0)	0.30
Circumference of calf (cm)	36.3 (32.3-40.2)	0.47, *P* =0.0428
Sum of eight skin-folds (mm)	102.0 (64.2-136.4)	0.26
Sum of upper body skin-folds (mm)	80.0 (46.7-97.2)	0.19
Sum of lower body skin-folds (mm)	38.2 (224-51.1)	0.30
Body fat percentage (%)	26.8 (20.0-31.4)	0.34

Results are presented as median (IQR). R-values represent Spearman correlation coefficients. *P*-value is inserted in case of a significant association.

Table 2. *Association of skin-fold thicknesses with race time (n=19)*

		r
Pectoral skin-fold (mm)	5.2 (4.1-8.2)	0.33
Mid-axilla skin-fold (mm)	9.2 (6.0-15.9)	0.02
Triceps skin-fold (mm)	13.6 (8.8-15.1)	0.52, *P* =0.0217
Subscapular skin-fold (mm)	10.8 (7.5-13.7)	0.12
Abdominal skin-fold (mm)	15.0 (11.5-21.0)	0.29
Suprailiac skin-fold (mm)	16.4 (5.5-25.3)	0.23
Front thigh skin-fold (mm)	24.4 (12.7-26.9)	0.29
Medial calf skin-fold (mm)	6.0 (4.0-11.3)	- 0.04

Results are presented as median (IQR). R-values represent Spearman correlation coefficients. *P*-value is inserted in case of a significant association.

Table 3. *Association of training variables and pre race experience with race time (n=19)*

		r
Number of years participating in running (years)	7.0 (5.2-9.8)	- 0.04
Weekly kilometres ran (km)	60 (56-80)	- 0.15
Hours ran per week (h)	7 (6-8)	0.21
Number of weekly training units	4 (2-5)	0.20
Minimal distance per training session (km)	30 (12-40)	- 0.10
Maximal distance per training session (km)	85 (35-100)	- 0.24
Distance per run training session (km)	15 (12-18)	- 0.41
Duration of run training sessions (min)	90 (80-120)	- 0.55, *P* =0.0156
Average speed of the training sessions (km/h)	10.0 (8.7-10.1)	- 0.17
Number of finished marathons (n=17)	16 (9-27)	0.18
Personal best time in a marathon (min) (n=17)	234 (220-243)	0.63, *P* =0.0068

Results are presented as median (IQR). R-values represent Spearman correlation coefficients. *P*-value is inserted in case of a significant association.

Measurements and Calculations

The participants were asked to maintain a comprehensive training diary consisting of daily workouts showing distance and duration in the preparation for the race. The training record consisted of the number of training units showing duration, kilometres and pace, weekly kilometres ran, weekly hours ran, minimal and maximal kilometres ran per week were also recorded. The athletes recorded their running speed during training in min/km. Additionally, they reported on the number of years that they had actively participated in running, the number of marathons that were successfully completed and the best times that were achieved in the marathon.

Before the start of the race body mass, body stature, length of leg, circumferences of limbs and thicknesses of skin-folds were measured. One trained investigator took all the measurements as inter-tester variability is a major source of error in anthropometric measurements. With this data, we calculated body mass index, the sum of upper and lower body skin-folds and percent body fat using anthropometric methods. Body mass was measured to the nearest 0.1 kg using a Beurer® BF15 scale (Beurer GmbH, Ulm, Germany). Body stature was determined to the nearest 1 cm using a stadiometer. Body mass index was calculated from body mass and body stature in kg/m^2. The skin-fold thicknesses were measured by the same investigator at the following eight sites: pectoral, triceps, mid-axilla, subscapular, abdominal, suprailiac, front thigh and medial calf. The skin-fold data was obtained using a skin-fold calliper (GPM-Hautfaltenmessgerät, Siber & Hegner, Zurich, Switzerland) and recorded to the nearest 0.2 mm. The measurements were made three times on the right side and the mean of the three results was used for the analyses. The timing of the taking of the skin-fold measurements was standardised to ensure reliability. Readings were performed 4 s after applying the calliper, according to the guidelines of Becque *et al.* [34]. The circumference of the upper arm was measured in the middle of the right upper arm (between *acromion* and *olecranon)* to the nearest 0.1 cm, the circumference of the right thigh was taken at the front thigh where the skin-fold thickness of front thigh was measured (20 cm above the upper margin of the patella), and the circumference of the right calf was measured at the maximum circumference of the calf. Circumferences of limbs were measured using a nonelastic tape measure (cm) (KaWe CE, Kirchner und Welhelm, Germany). Percent body fat was calculated using the formula: Percent body fat = -6.40665 + 0.41946 (Σ3SF) – 0.00126 (Σ3SF)^2 + 0.12515 (Hip) + 0.06473 (age) using the formula of Ball *et al.* [35]. Σ3SF was taken as the sum of the three skin-fold thickness of the triceps, suprailiac and front thigh skin-fold thicknesses. Hip was the circumference of the hip measured at the largest perimeter.

Statistical analysis

The Shapiro-Wilk test was used to check for normality distribution. Non-normally distributed data is presented as median (interquartile range, IQR). The coefficient of variation of performance (CV % = 100 x SD/mean) for total race time was calculated. As a first step, the association of the variables of pre race experience, training and anthropometry with total race time was investigated using bivariate correlation analysis to reduce variables for multivariate analysis. Spearman correlation analysis was applied since the data was non-normally distributed. In a second step, multivariate linear regression analysis was used to further investigate the relationship of variables with significances in the bivariate analysis to race time. Stepwise multiple regression analysis was then used to determine the best variables correlated with the race performance. A probability value of less than 0.05 was accepted as significant.

Results

A total of 353 females completed the race where the female winner took 7:54 h: min. All our participants finished the race within 12:48 h: min (CV = 13.4 %). The female winner completed the 100 km within 7:54 h:min, the subjects finished within 162 (21) % of the winner time. In the bivariate analysis (Tables 1-3), age (r = - 0.46), body mass (r = 0.55), body stature (r = 0.47), circumference of upper arm (r = 0.54), circumference of calf (r = 0.47), thickness of triceps skin-fold (r = 0.52), duration of run training sessions (r = - 0.55) and personal best marathon time (r = 0.63) were significantly related to race time. When all variables with significant bivariate association entered the multivariate analysis (***Table 4***), the thickness of triceps

Table 4. *Associations between race time as dependent variable and significant variables after bivariate analysis using multiple linear regression (n=17)*

	β	SE	*P* -value
Age	- 2.8	2.4	0.26
Body mass	- 1.0	8.2	0.89
Body stature	222	503	0.67
Circumference of upper arm	- 20.0	11.4	0.11
Circumference of calf	- 14.1	12.8	0.30
Triceps skin-fold	13.9	6.0	0.04 *
Duration of run training sessions	- 2.0	- 1.32	0.22
Personal best time in marathon (n=17)	2.66	1.12	0.04 *

ß = regression coefficient; SE = standard error of the regression coefficient; Coefficient of determination (R^2) of the model was 78%. Triceps skin-fold and personal best marathon time were related to race time. Out of the 19 participants, 17 had performed a marathon before the 100 km run.

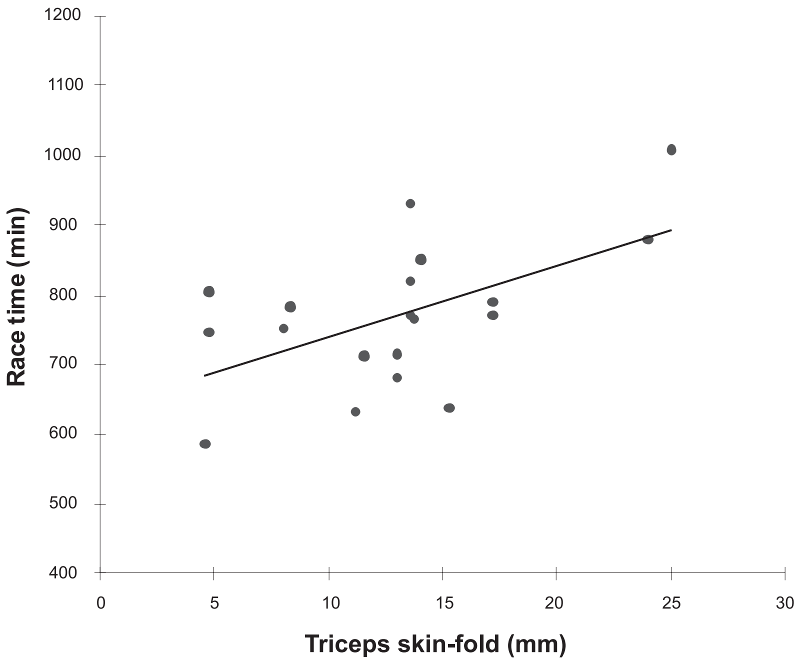

Fig. 1. *Triceps skin-fold thickness was positively and significantly related to race time (r = 0.52, P =0.0217) (n=19)*

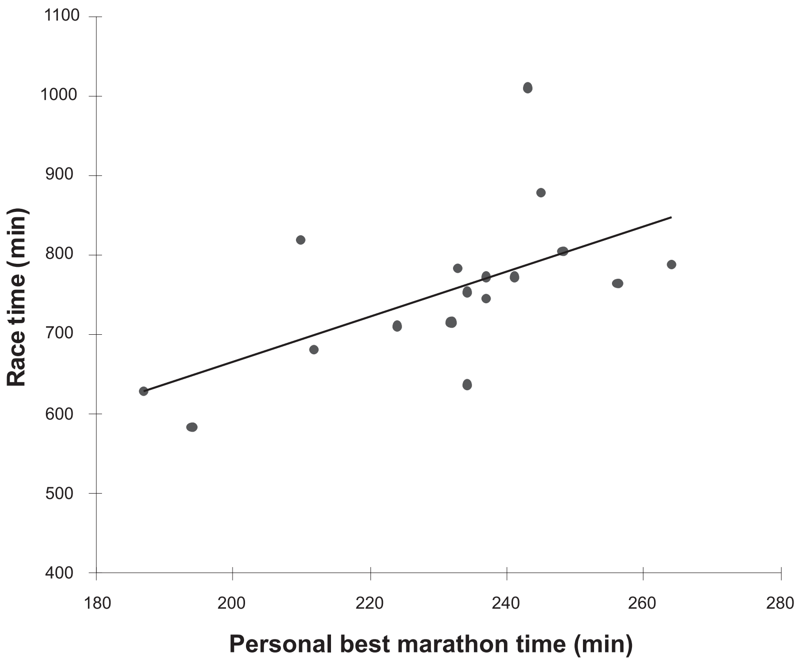

Fig. 2. *Personal best marathon time was positively and significantly related to race time. Seventeen athletes had performed a marathon pre race (r = 0.63, P =0.0068) (n=17)*

skin-fold (Fig. 1) and personal best time in a marathon (Fig. 2) remained the single predictor variables. Race time for female 100 km ultra-marathoners might be predicted by the following equation (n=17, $r^2 = 0.52$): Race time (min) = 183.1 + 7.6 x (triceps skin fold, mm) + 2.1 x (personal best marathon time, min)

Discussion

Considering the present literature on distances up to the marathon, we hypothesised finding an association between both anthropometric variables, such as skin-fold thicknesses, training variables and pre race experience with race performance. As we hypothesised, we found an association between skin-fold thicknesses and race performance. However, in contrast to runners over the marathon distance where abdominal and front thigh skin-fold were correlated [14], we found an association between triceps skin-fold thickness and performance in these female 100 km ultra-runners. The thickness of triceps skin-fold might be of importance in female long-distance runners. Legaz-Arrese *et al.* found a higher triceps and thigh skin-fold thickness in female marathon runners compared to males [36]. All other skin-folds showed no differences between genders in their investigation. Since triceps skin-fold thickness was related to performance we might assume that upper body anthropometry might be associated with ultra-running performance in females as has been found for males where circumference of upper arm was related to performance [8, 19]. Regarding Table 1, in these female ultra-runners, also, circumference of the upper arm was related to performance in the bivariate analysis. However, circumference of the calf was also related, but apart from the triceps skin-fold thickness, neither a single upper body skin-fold nor the sum of upper body skin-folds was related to race time.

We hypothesised also finding an association between variables of pre race experience and training with race time. In the bivariate analysis, average duration of the training sessions and personal best marathon time were related. Apart from anthropometry, pre race experience might be of importance. In female marathon runners, Christensen and Ruhling concluded that performance in female marathoners was more associated with years of training than body dimensions [26]. Also Bale *et al.* found that the number of training sessions and the number of years training were the best predictors of competitive performance in female marathoners [24]. In contrast to their findings, the number of years participating in running was not related to performance in our subjects.

However, in female long-distance runners, both anthropometry and training seems to be related to marathon performance time. According to Hagan *et al.*, both variables of anthropometry and training seem to account for marathon performances in females [11]. In their sample of 35 female distance runners, marathon performance time was related to body mass index, maximal oxygen uptake, previous marathons completed, workout days, workouts per two days, total workouts, total training duration, training pace and distance in training. Hagan *et al.* investigated a total of 11 variables of pre race experience and training; nine of these 11 variables were related to marathon performance time [11]. In this present study, also 11 variables were investigated, but only two of these 11 were related to the 100 km performance time. A possible reason for these different findings might be that Hagan *et al.* investigated marathon runners, not ultra-marathoners, and that they did not ask for the duration of training sessions or personal best marathon times [11].

In the bivariate analysis, personal best time in a marathon showed the highest correlation coefficient. Also when we corrected with the covariates in the regression models, personal best time in a marathon was significantly related to race time. This finding was previously reported in ultra-runners during a 24-hour run, where personal best marathon time was significantly and positively correlated to the achieved distance during the run [31]. Furthermore, successful finishers in a multi-stage ultra-endurance run over 1,200 km with 17 stages had a significantly faster personal best marathon time compared to non finishers [20]. In both studies, however, anthropometric variables showed no association with ultra-endurance performance.

Limitations of the study

This cross-sectional study is limited regarding the influence and effects of anthropometry and training on race performance in ultra-endurance runners, since only an intervention trial can answer this question. Other limitations are lack of fitness evaluation of these athletes. We focused this investigation on anthropometry, pre race experience and training. Other aspects such as nutrition and influence of environment were not considered. The small sample size might limit statistical calculations. However, when regarding the literature about female ultra-endurance runners, Speechly *et al.* were reporting results about 19 female ultra-runners (90 km) performing a 90 km ultra-marathon [32]. Although Hoffman could describe 82 female ultra-runners in a 161-km trail run, they could only provide the anthropometric characteristics body mass, body height and body mass index, but no skin-fold thicknesses or training variables [12].

Conclusions

This observational cross-sectional study assessed the association between variables of anthropometry and training with running performance in female 100 km ultra-runners. From this analysis, it is concluded that both anthropometry and pre race experience are associated with race performance in female 100 km ultra-runners, but not training parameters. Since a cross-sectional study with correlation analysis cannot provide cause and effect, a longitudinal study is needed. Furthermore, in a larger sample of female ultra-runners the association of training variables and race performance might lead to different findings.

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