

A Comparison of Anthropometric and Training Characteristics between Female and Male Half-Marathoners and the Relationship to Race Time

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Abstract

Purpose: Lower limb skin-fold thicknesses have been differentially associated with sex in elite runners. Front thigh and medial calf skin-fold appear to be related to 1,500m and 10,000m time in men but 400m time in women. The aim of the present study was to compare anthropometric and training characteristics in recreational female and male half-marathoners.

Methods: The association between both anthropometry and training characteristics and race time was investigated in 83 female and 147 male recreational half marathoners using bi- and multi-variate analyses.

Results: In men, body fat percentage ($\beta=0.6$), running speed during training ($\beta=-3.7$), and body mass index ($\beta=1.9$) were related to half-marathon race time after multi-variate analysis. After exclusion of body mass index, r^2 decreased from 0.51 to 0.49, but body fat percentage ($\beta=0.8$) and running speed during training ($\beta=-4.1$) remained predictive. In women, body fat percentage ($\beta=0.75$) and speed during training ($\beta=-6.5$) were related to race time ($r^2=0.73$). For women, the exclusion of body mass index had no consequence on the predictive variables for half-marathon race time.

Conclusion: To summarize, in both female and male recreational half-marathoners, both body fat percentage and running speed during training sessions were related to half-marathon race times when corrected with co-variables after multi-variate regression analyses.

Key Words: Body Fat; Running Speed; Body Mass Index

INTRODUCTION

Running is of high popularity and can be performed over different distances [1, 2] such as 100 m [3], 200 m [4], 400 m [5], 5,000 m [6], the half-marathon distance [7,8], the marathon distance [9,10] and different ultra-marathon distances [11]. Different characteristics in physiology, training and anthropometry seem to influence running performances [12-15].

Regarding training, in one study, both volume and intensity appeared to influence running performance [16]. In another study, Bale et al. investigated 60 athletes of three different levels in training for a national

10,000 m road race championship [17]. The top-class athletes performed faster over the 10,000 m distance [17] after higher training frequency, higher volume of weekly training and more running experience than athletes of lower level. Billat et al. [18] also reported that elite marathoners trained for more weekly kilometers and at a higher velocity than non-elite marathoners. And in another study, the peak of running velocity during training was highly associated with 5,000 m running times regardless of gender [19].

Anthropometry also seems to play an important role in running times. Several studies, for example, have shown positive associations between anthropometric

characteristics including body mass [20-22], body mass index [21,23,24], body fat percentage [21,24,25], skin-fold thickness of the lower body [26, 27], the circumference of upper arm [21,22,28] and the circumference of calf [29] and running times. On the other hand, no significant correlations have also been reported between anthropometric characteristics including body mass index, skeletal muscle mass, leg length, skinfold thicknesses or limb circumferences; and race time in multi-sports athletes competing in a Deca Iron ultra-triathlon [30].

Moreover, the association of running performance with both single skin-fold thicknesses and the sum of skin-folds has been intensively investigated [26,27,31,32]. One study found significant negative correlations between the sum of seven skin-fold thicknesses and marathon race times [31]. However, significant positive correlations have also been reported between running times and the thickness of selected skin-folds, in elite runners of 100 m to 10,000 m and marathon distances [26,32]. The anterior thigh and the medial calf skin-fold were positively correlated with both 1,500 m and 10,000 m race times in male runners [26]. Another study also found a significant association of the calf skin-fold with total race distance over 350 km with 11,000 m of altitude in a 7-day mountain ultra-marathon [27].

In the running disciplines, the half-marathon distance has been the fastest growing road race distance in the United States of America since 2003 [33]. For seven consecutive years between 2006 and 2012, the number of half-marathon finishers has increased by at least 10% each year. Since 2000, the number of half-marathon finishers in the United States of America has nearly quadrupled from 482,000 to 1,850,000 with an impressive increase of 284%. For the first time in history, 60% of these half-marathon finishers were women.

While there is abundant literature on the association between both anthropometric and training characteristics and race times from 100 m to the marathon distance [9,17,20,23,25,26], the amount of data available from female and male half-marathoners remains limited [7,8,34]. The differences in anthropometry between male and female half-marathoners have been described previously [34] and the anthropometric characteristics showed differential sex correlations with

running times [7,8,34]. Rüst et al [8] analyzed recreational male runners and found a positive correlation between body mass index and race time but running speed during training correlated negatively with running times in recreational male half-marathoners. Knechtle et al. [7] also found a positive relationship between mid-axilla skin-fold thickness and running times in recreational female half-marathoners. In both men and women, running speed during training sessions correlated significantly and negatively to half-marathon race time. In another study [34], anthropometric variables were positively correlated to half-marathon performance times in both men and women. Compared to men, the anthropometric variables in women (sum of 8 skin-folds: women $\beta=0.28$, men $\beta=0.06$; body mass index: women $\beta=0.97$, men $\beta=2.25$; mean speed of the training session: women $\beta=-3.98$, men $\beta=66.97$, respectively) were significantly associated to half-marathon race times.

However, the findings in these two studies might have been influenced by the rather small sample size. Knechtle et al. [7] investigated 84 male half-marathoners while Rüst et al. [8] described only 42 female half-marathoners. The aim of the present study was to compare anthropometry and training between recreational men and women in a larger sample of half-marathoners. First, we hypothesized that female and male half-marathoners would differ in both anthropometric and training characteristics. Secondly, we hypothesized that half-marathon race times would differ with anthropometric characteristics according to gender.

METHODS AND SUBJECTS

Subjects and races:

The 'Basel Marathon' held in Basel, Switzerland was the setting of choice to carry out this study. In this marathon, athletes normally run either a half-marathon or a marathon. The half-marathon, target of this study, involves running one lap of 21.0975 km on asphalt with a total altitude of 200 m. All female and male

half-marathoners participating in the 2010 and 2011 edition of this half-marathon were informed via electronic newsletters sent by the organizer three months before the race. Information about the planned investigation was also provided on the race website. Participating athletes were included only once and recruited continuously during two consecutive years from 2010 to 2011, in order to increase the sample size. Course and nutrition for athletes and general weather conditions were nearly identical in both years. The study was approved by the Institutional Review Board for use of Human Subjects of the Canton of St. Gallen, Switzerland. All athletes participating in the study were informed of the experimental procedures and gave informed written consent.

Measurements and Calculations:

The participants were asked to record the amount and units of their training for a period of three months, commencing upon study registration until the race date. The investigator provided an electronic file where the subjects could insert each training unit with distance in kilometers (km), duration in minutes (min) and speed in kilometers per hour (km/h). The investigator calculated the mean weekly training hours, the mean weekly training kilometers achieved and the mean running speed during training in the pre-race preparation. The participants were also asked to report the number of completed half-marathons and their personal best time in half-marathon. The personal best time in half-marathon was defined as the fastest time ever achieved during life in half-marathon running.

On the afternoon of the day before the races, the following anthropometric characteristics were measured: body mass, body height, the circumferences of the limbs, the length of the leg and the thicknesses of skin-folds at pectoral, mid-axilla, triceps, subscapular, abdominal, suprailiacal, front thigh and medial calf site. The circumferences of the limbs and skin-fold thicknesses were measured on the right side of the body. The body mass index was calculated using these anthropometric data. Both the percentage of body fat and the skeletal muscle mass were estimated using 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 (Tanita HR 001 Portable Height Measure, Tanita Europe, Amsterdam, Netherlands) to the nearest 1.0 cm. The length of the leg and the circumferences of the limbs were measured using a non-elastic measuring (cm) tape (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 mid-calf. All skin-fold data were obtained using a skin-fold calliper (GPM-Hautfaltenmessgerät, Siber & Hegner, Zurich, Switzerland) and recorded to the nearest 0.2 mm. The skin-fold caliper measures with a pressure of 0.1 MegaPascal (Mpa) \pm 5% over the whole measuring range. The skin-fold measurements were taken once for all eight skin-fold sites, and then the procedures were repeated twice more by the same investigator. The mean of the three measurements was used for calculation. The timing of the skin-fold measurements was standardized to ensure reliability. It has been suggested that the best readings are those performed 4 sec after applying the caliper [35]. One trained investigator took all skin-fold measurements as inter-tester variability is a major source of error in skin-fold measurements. Intra- and inter-rater agreement was assessed from 27 male runners prior to an ultra-marathon, based on measurements taken by two experienced primary care physicians [36]. Intra-class correlation (ICC) within the two raters was excellent for all anatomical measurement sites and for various summary measurements of skin-fold thicknesses (ICC>0.9). Agreement tended to be higher within than between raters, but still reached excellent reliability. That is, ICC=0.99 (0.99-1.00 95% confidence interval) for the summary measurements of skin-fold thicknesses between raters. ICC for investigator 1 versus investigator 1 and for investigator 2 versus investigator 2 for the single skin-fold thicknesses were between 0.98 and 0.99 respectively. For the sum of seven and eight skin-folds ICC was 0.99-1.00. For the sum of eight skin-folds 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.

For women, percentage of body fat was estimated using the formula percentage of body fat = $-6.407 + 0.419 (\Sigma 3SF) - 0.001 (\Sigma 3SF)^2 + 0.125 (\text{hip}) + 0.065 (\text{age})$ following Ball et al [37]. $\Sigma 3SF$ was taken as the sum of the three skin-fold thickness of the triceps, suprailiac and front thigh skin-fold. Hip was the circumference of the hip. For men, percentage of body fat was estimated using the anthropometric formula according to Ball et al [38] with percent body fat = $0.465 + 0.180 \times (\Sigma 7SF) - 0.0002 \times (\Sigma 7SF)^2 + 0.066 \times (\text{age})$, where $\Sigma 7SF$ is the sum of skin-fold thickness of pectoralis, axillar, triceps, subscapular, abdomen, suprailiacal and thigh mean in mm and age is in years. Skeletal muscle mass (SMM) was estimated for both sexes using the formula of Lee et al [39] with $SMM = Ht \times (0.007 \times CAG^2 + 0.001 \times CTG^2 + 0.004 \times CCG^2) + 2.4 \times \text{sex} - 0.048 \times \text{age} + \text{race} + 7.8$ where Ht = height, CAG = skin-fold-corrected upper arm girth, CTG = skin-fold-corrected thigh girth, CCG = skin-fold-corrected calf girth, sex = 1 for men; age is in years; race = 0 for white men and 1 for black men. This equation was validated using magnetic resonance imaging (MRI) to determine skeletal muscle mass. There was a high correlation between the predicted skeletal muscle mass and the MRI-measured skeletal muscle mass ($r^2=0.83$, $P<0.0001$, $SEE=2.9\text{kg}$). 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). Prior to analysis, data were checked for distribution of normality and are presented as mean \pm standard deviation (SD). The coefficient of variation (CV) of performance ($CV\% = 100 \times SD/\text{mean}$) was calculated. The coefficient of variation describes the magnitude sample values and the variation within them. Data for the female and male half-marathoners were compared using the Mann-Whitney U-test. To investigate a potential association between anthropometric and training characteristics with race time, in a first step, the relationship between race time 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 for the multivariate analysis, Bonferroni correction was applied ($P<0.0017$ for 29 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 $r > 0.9$. For the strength of a correlation, $r > 0.70$ indicated a very strong, $r = 0.40-0.69$ a strong, $r = 0.30-0.39$ a moderate, $r = 0.20-0.29$ a weak and $r = 0.01-0.19$ a negligible relationship, respectively. A power calculation was performed according to Gatsonis and Sampson [40]. 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

A total of 83 female and 147 male half-marathon runners were investigated. Women completed the half-marathon within 125.7 ± 16.7 min (CV 13.8%), running at a mean speed of 10.2 ± 1.3 km/h. Expressed in percent of the course record (1 h 31 min of Jennifer Eyermann in 2010), women finished within $138 \pm 18\%$. Men finished within 106.8 ± 17.3 min (CV 16.2%), while running at a mean speed of 12.2 ± 1.9 km/h. They finished within $157 \pm 21\%$ of the course record of 1 h 8 min set by Berhane Ogubit in 2011. Men ran significantly faster compared to women ($P<0.0001$). When the performance expressed in percent of the course record was compared between the sexes, women were significantly faster than men ($P<0.001$).

Regarding anthropometry, women had a lower body mass, a shorter body height, and a lower body mass index (Table 1). The circumferences of upper arm and calf were smaller in women; the thigh circumference showed no statistically significant gender difference. Women had a thicker skin-fold at triceps, thigh and

Table 1: Comparison of anthropometric and training characteristics between female and male half-marathoners

Variable	Women (n=83)	Men (n=147)	P. value
	Mean (SD)	Mean (SD)	
Age (years)	38.3 (9.2)	40.2 (10.1)	NS
Body mass (kg)	60.1 (7.8)	75.8 (8.6)	<0.001
Body height (m)	1.66 (0.06)	1.79 (0.06)	<0.001
Body mass index (kg/m ²)	21.7 (2.3)	23.3 (2.2)	<0.001
Length of leg (cm)	82.9 (3.6)	87.7 (4.8)	<0.001
Circumference of upper arm (cm)	26.6 (1.8)	29.7 (2.0)	<0.001
Circumference of thigh (cm)	55.4 (3.8)	55.9 (3.2)	NS
Circumference of calf (cm)	36.5 (2.5)	38.2 (2.5)	<0.001
Skin-fold pectoral (mm)	8.5 (4.5)	9.4 (4.2)	NS
Skin-fold axilla (mm)	10.4 (4.5)	10.6 (4.3)	NS
Skin-fold triceps (mm)	13.5 (4.3)	8.6 (2.8)	<0.001
Skin-fold subscapular (mm)	10.5 (4.5)	11.3 (4.3)	<0.05
Skin-fold abdominal (mm)	16.9 (6.5)	18.8 (9.1)	NS
Skin-fold iliacal (mm)	20.7 (8.3)	20.8 (9.4)	NS
Skin-fold thigh (mm)	26.4 (9.4)	13.7 (6.1)	<0.001
Skin-fold calf (mm)	10.3 (4.8)	6.7 (2.7)	<0.001
Sum of skin-folds (mm)	117.3 (38.3)	99.9 (35.6)	<0.001
Percent body fat (%)	28.4 (5.3)	17.5 (4.6)	<0.001
Skeletal muscle mass (kg)	27.6 (2.7)	39.1 (3.1)	<0.001
Years as active runner (y)	6.1 (5.0)	7.9 (8.0)	NS
Weekly running kilometers (km)	33.5 (17.0)	33.7 (20.5)	NS
Minimal weekly distance (km)	15.5 (10.1)	16.2 (13.5)	NS
Maximal weekly distance (km)	41.6 (18.5)	45.2 (29.1)	NS
Weekly running hours (h)	3.6 (1.8)	3.9 (2.0)	NS
Number of training units (n)	3.0 (1.0)	3.1 (1.3)	NS
Distance per training unit (km)	10.4 (2.9)	11.3 (3.2)	NS
Duration per training unit (min)	63.5 (16.0)	63.0 (16.5)	NS
Speed in running training (km/h)	9.8 (1.5)	10.8 (1.5)	<0.01
Number of completed races (n)	5 (2); n=43	6 (7); n=108	<0.05
Personal best time (min)	115 (21)	102 (17)	<0.01

SD: Standard Deviation; NS: Non-significant

calf site compared to men. At subscapular site, women possessed a thinner skin-fold than men. Women had a higher sum of total skin-fold thicknesses, a higher percent of body fat and a lower skeletal muscle mass compared to men. For the training characteristics, no gender differences were found in the volume of training. Women were running slower during training, had completed fewer previous half-marathons and had a slower personal best half-marathon race time compared to men.

Significant variables after bi-variate analysis of both anthropometry and training related to half-marathon race time (Table 2) were multi-variately correlated to half-marathon race times. For women (Table 3), body

fat percentage and running speed during training sessions were significantly correlated to half-marathon race times. For men (Table 4), body fat percentage, running speed during trainings session and body mass index were significantly correlated to half-marathon race times.

In a second model, body mass index was excluded. Multi-variate analysis in women, showed no influence on the predictor variables. In men, however, the coefficient of determination (r^2) decreased from 0.51 to 0.49. For both women (Fig. 1) and men (Fig. 2), the running speed during training was significantly and negatively associated with the percentage of body fat, respectively.

Table 2: Association between anthropometric and training characteristics with race time for female and male half-marathoners

Variable	Women (n=83)		Men (n=147)	
	r	P	r	P
Age	0.27	0.01	0.27	0.001
Body mass	0.63	<0.0001	0.27	0.0009
Body height	0.27	0.01	-0.17	0.04
Body mass index	0.57	<0.0001	0.46	<0.0001
Length of leg	0.16	0.1	-0.21	0.01
Circumference of upper arm	0.55	<0.0001	0.37	<0.0001
Circumference of thigh	0.51	<0.0001	0.15	0.07
Circumference of calf	0.53	<0.0001	0.14	0.08
Skin-fold pectoral	0.48	<0.0001	0.43	<0.0001
Skin-fold axilla	0.56	<0.0001	0.41	<0.0001
Skin-fold triceps	0.45	<0.0001	0.35	<0.0001
Skin-fold subscapular	0.52	<0.0001	0.39	<0.0001
Skin-fold abdominal	0.54	<0.0001	0.44	<0.0001
Skin-fold iliacal	0.39	0.0002	0.35	<0.0001
Skin-fold thigh	0.49	<0.0001	0.29	0.0004
Skin-fold calf	0.59	<0.0001	0.48	<0.0001
Sum of skin-folds	0.58	<0.0001	0.47	<0.0001
Percent body fat	0.60	<0.0001	0.49	<0.0001
Skeletal muscle mass	0.24	0.03	-0.07	0.4
Years as active runner	-0.16	0.1	-0.02	0.8
Weekly running kilometers	-0.20	0.07	-0.48	<0.0001
Minimal weekly distance	-0.30	0.006	-0.36	<0.0001
Maximal weekly distance	-0.18	0.1	-0.46	<0.0001
Weekly running hours	-0.11	0.3	-0.30	0.0002
Number of training units	-0.06	0.6	-0.42	<0.0001
Distance per training unit	-0.29	0.007	-0.32	<0.0001
Duration per training unit	-0.03	0.7	-0.2	0.01
Speed in running training	-0.77	<0.0001	-0.58	<0.0001
Number of completed races	-0.08	0.6	-0.13	0.1
Personal best time	0.35	0.1	0.85	<0.0001

Variables with *P*. values of <0.0017 are used for the multi-variate analysis (n=29 variables)

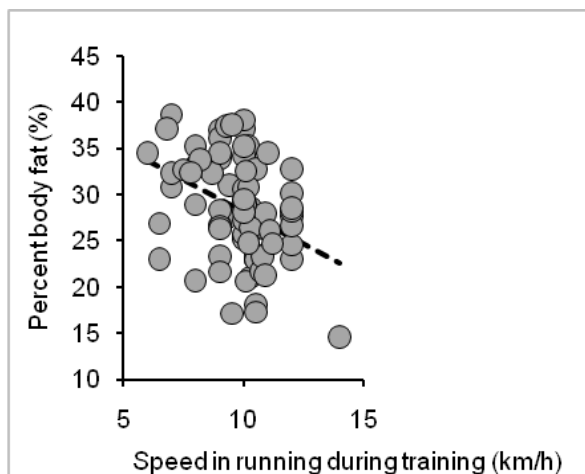


Fig. 1: For women, percentage of body fat was significantly and negatively related to running speed during training ($r=-0.38$, $P=0.0005$).

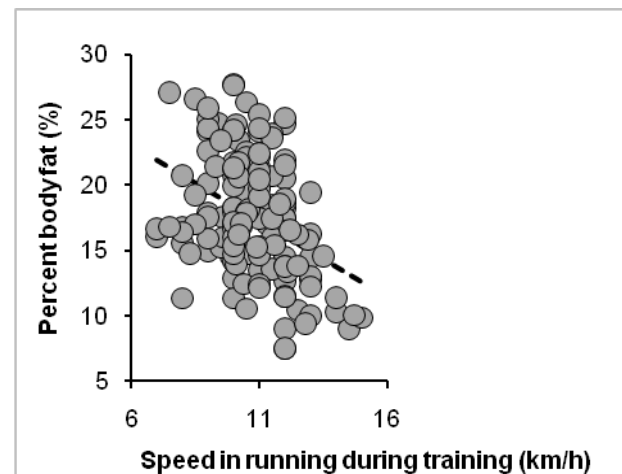


Fig. 2: For men, percentage of body fat was significantly and negatively associated with running speed during training ($r=-0.39$, $P<0.0001$).

Table 3: Associations between significant characteristics after bi-variate analysis and race time for women using multiple linear regression

Women (n=83)	β	SE	P
Body mass	0.09	0.3	0.8
Body mass index	0.9	0.9	0.3
Circumference of upper arm	0.3	0.8	0.7
Circumference of thigh	-0.1	0.5	0.8
Circumference of calf	0.9	0.7	0.2
Percent body fat	0.75	0.2	0.003
Speed in running training	-6.5	0.8	<0.0001
Body mass	0.3	0.2	0.3
Circumference of upper arm	0.4	0.8	0.6
Circumference of thigh	0.04	0.4	0.9
Circumference of calf	0.8	0.7	0.3
Percent body fat	0.7	0.2	0.003
Speed in running training	-6.5	0.8	<0.0001

β = regression coefficient; SE= standard error of the regression coefficient; the coefficient of determination (r^2) of the model was 0.73.

Percentage of body fat and running speed during training were associated with half-marathon race time. When body mass index was excluded, r^2 remained unchanged at 0.73, and both percentage of body fat and running speed during training remained predictive

DISCUSSION

The aim of the present study was to compare anthropometric and training characteristics between

female and male recreational half-marathon runners in a larger sample of runners than in previous studies [7, 8].

Based on the existing literature, we first hypothesized that female and male half-marathoners would differ in

Table 4: Associations between significant characteristics after bi-variate analysis and race time for men using multiple linear regression

Men (n=147)	β	SE	P
Body mass	-0.3	0.2	0.1
Body mass index	1.9	0.8	0.01
Circumference of upper arm	0.1	0.6	0.9
Percent body fat	0.6	0.3	0.03
Weekly running kilometers	-0.2	0.1	0.1
Minimal weekly running distance	-0.1	0.1	0.3
Maximal weekly running distance	0.003	0.06	0.9
Weekly running hours	1.4	0.9	0.1
Number of training units	-1.8	1.3	0.1
Distance per training unit	-0.3	0.4	0.4
Speed in running training	-3.7	0.8	<0.0001
Body mass	0.004	0.1	0.9
Circumference of upper arm	0.5	0.6	0.4
Percent body fat	0.8	0.3	0.008
Weekly running kilometers	-0.2	0.1	0.1
Minimal weekly running distance	-0.1	0.1	0.3
Maximal weekly running distance	-0.005	0.07	0.9
Weekly running hours	1.0	0.9	0.2
Number of training units	-1.4	1.3	0.3
Distance per training unit	-0.3	0.4	0.4
Speed in running training	-4.1	0.8	<0.0001

β = regression coefficient; SE= standard error of the regression coefficient; the coefficient of determination (r^2) of the model was 0.51. Body mass index, percentage of body fat and running speed during training were related to half-marathon race time. When body mass index was excluded, r^2 remained decreased to 0.49, and both percentage of body fat and running speed during training remained predictive

both anthropometric and training characteristics. Secondly, we expected anthropometric characteristics to be differentially associated with half-marathon race times according to gender.

Comparison of anthropometry and training between women and men:

The most important finding was that men and women showed the same predictor variables for half-marathon race time in anthropometry and training characteristics including body fat percentage (women: $\beta=0.7$, men: $\beta=0.8$), and running speed during training (women: $\beta=-6.5$, men: $\beta=-4.1$). Also, for recreational marathoners, men showed the same predictor variables for the race time including body fat ($\beta=0.504$) and running speed during training sessions ($\beta=-0.57$)^[41]. For recreational female marathoners, however, the circumference of calf ($r=-0.41$, $P=0.02$) and running speed during training sessions ($r=-0.60$, $P=0.0005$) were positively associated with marathon race times in the multivariate analysis^[29].

As expected, men and women showed differences in their anthropometric characteristics. The most important differences found were for body mass, body height, body mass index, leg length, circumference of upper arm and calf, body fat percentage, the sum of eight skin-folds (e.g. pectoral, axilla, triceps, subscapular, abdominal, iliacal, thigh and calf) and skeletal muscle mass. Knechtel et al^[34] investigated anthropometric variables in female and male half-marathon runners. They found significant differences in body mass, body height and body mass index, differences in several skin-fold thicknesses (i.e. triceps, front thigh and medial calf) and body fat percentage. In contrast to their findings, the present study included further anthropometric characteristics including leg length, the circumferences of both upper arm and calf and skeletal muscle mass. The inclusion of these variables and the larger sample might explain the difference in findings.

Another important difference is that in the present study, the sum of eight skin-folds showed a significant gender difference. The sum of eight skin-folds was higher for women than for men. However, in keeping with Knechtel et al^[34], the sum of skin-folds was not different between men and women. We assume these

differences are due to the larger sample of runners. Other more recent studies investigated 42 female half-marathoners^[7], and 84 male half-marathoners^[8]. The present study, however, included two times the subjects with 83 women and 147 men. In the current study and in the study of Knechtel et al^[34] investigating 15 women and 52 men, women showed highly significant skin-folds for three variables (i.e. triceps, thigh and calf) which also were thicker than those in men. This might be due to the fact that men have lower body fat percentage and higher skeletal muscle mass. All other variables such as age, circumference of thigh, thickness of pectoral, axillar, abdominal and suprailiacal skin-folds showed no significant gender differences.

As far as training characteristics were concerned, men ran faster during training than women, had a faster personal best time and had completed more races than women. Besides, in the study of Knechtel et al. investigating differences in anthropometric and training characteristics in female and male half-marathoners^[34], men ran significantly faster during training than women, but there were no significant differences in the amount of running, and personal best times were not reported.

Correlation of anthropometric and training characteristics with race time:

For both men and women, body fat percentage was positively and the running speed during training sessions was negatively associated with half-marathon race times after correction of co-variables in the multivariate analysis. In recreational male marathoners, race time correlated to body fat percentage and running speed during training sessions^[41]. Marathon race time was faster when body fat was lower and running speed during training was higher. In recreational female marathoners, running speed of the training session was related to marathon race time, whereas body fat percentage was not related to performance^[29]. In contrast, the circumference of calf as an anthropometric variable was related to race time^[29]. A possible explanation for the gender differences between the studies could be the anthropometry of the runners and the sample sizes.

Arrese and Ostariz^[26] reported that various skin-fold thicknesses showed different associations with the

different running distances. Presumably, the explanation for the different findings regarding the present results was that Arrese and Ostariz [26] investigated a smaller sample size of high-level runners and their results were not corrected with co-variables like training. In the present study, body fat percentage and running speed explained 73% of the variance in recreational female runners but only 51% (with body mass index) and 49% (without body mass index) in recreational men runners. In contrast, Knechtle et al [7] reported that mid-axilla skin-fold and mean speed of the training correlated with the race time in recreational female half-marathoners. These different results were probably due to the larger sample size in the present study. In addition, Rüst et al [8] only reported a positive correlation in body mass index with half-marathon race time of male runners and a negative correlation in speed of the training session with race time. In the current study, body fat percentage played an important role for male runners as well ($\beta=0.8$). The most likely reason for the different findings was again the sample size.

We excluded body mass index in a second multivariate analysis for men and the coefficient of determination (r^2) decreased from 0.51 to 0.49. The difference of 2% seems to show that body mass index has only a minor influence on race time in men. Body fat percentage and speed during training still correlated with race time for men. On the contrary, for women, the exclusion of the body mass index showed no consequences for the predictive values of the race time with no change in r^2 . For both men and women body fat percentage and the running speed during training were of importance. For men, the coefficient of determination ($r^2=0.49$) was lower when compared to women ($r^2=0.73$). The included variables of anthropometry and training might not fully explain the performance in half-marathoners since aspects of physiology and psychology might also considerably influence running performance.

Association between anthropometry and training characteristics:

The predictor variables of body fat percentage and running speed during training were important for half-marathon race times for both men and women. We

found a significant and negative correlation between running speed during training and body fat percentage for both women and men. This relationship was moderate for both men ($r=0.39$) and women ($r=0.38$). This association might show that a fast running speed during training leads to a low body fat. However, a correlation does not prove cause and effect. Athletes can reduce their body fat also by diet with restriction of calorie intake.

Strength, weakness, limitations and implications for future research

The strength of the present study was the large sample of 83 female and 147 male half-marathoners. A weakness was that the extremity/trunk skin-fold ratio (E/T ratio) [34] was not included as an anthropometric variable. Furthermore, physiological characteristics such as maximum oxygen uptake [42] and lactate threshold [43] which are considered to influence running time were not included. Also, data about nutrition [44] and motivation [45] of the subjects are missing. The results of this study can only be implemented for recreational half-marathoners but not for elite runners since only recreational athletes were included. Future studies need to investigate elite half-marathoners with inclusion of physiological and motivational aspects.

CONCLUSION

Despite the various differences in anthropometry and only one difference in training characteristics (*i.e.* speed during training) for both female and male recreational half-marathon runners, body fat percentage correlated positively and running speed during training correlated negatively with half-marathon race times for both men and women. The influence of body mass index as a predictor variable was lower than presumed. In addition, the sum of the skin-fold thicknesses seemed to be more important than the single folds. For practical applications, body fat percentage and running speed during training sessions were the best predictors for half-marathon race time in both female and male recreational runners.

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