Personal best marathon performance is associated with performance in a 24-h run and not anthropometry or training volume

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ABSTRACT

Objective: In this study, the influence of anthropometric and training parameters on race performance in ultra-endurance runners in a 24-h run was investigated.
Design: Descriptive field study.
Setting: 24-h run in Basel 2007.
Participants: 15 male Caucasian ultra-runners (mean (SD) 46.7 (5.8 years), 71.1 (6.8 kg), 1.76 (0.07 m), body mass index 23.1 (1.84 kg/m^2)).
Interventions: None.
Main outcome measures: Age, body mass, body height, length of lower limbs, skin-fold thicknesses, circumference of extremities, skeletal muscle mass, body mass, percentage of body fat, and training volume in 15 successful finishers were determined to correlate anthropometric and training parameters with race performance.
Results: No significant association ($p>0.05$) was found between the reached distance and the anthropometric properties. There was also no significant association between the reached distance with the weekly training hours, running years, the number of finished marathons and the number of finished 24-h runs. The reached distance was significantly ($p<0.05$) positively correlated with the personal best marathon performance ($r^2 = 0.40$) and the personal best 24-h run distance ($r^2 = 0.58$). Furthermore, the personal best marathon performance was significantly and positively correlated ($p<0.01$) with the best personal 24-h run distance ($r^2 = 0.76$).
Conclusions: Anthropometry and training volume does not seem to have a major effect on race performance in a 24-h run. Instead, a fast personal best marathon time seems to be the only positive association with race performance in a 24-h run.

In runners, several anthropometric parameters are known to influence performance—depending upon the distance run—such as body mass,[1–5] body height,[1 5] body mass index (BMI),[6] body fat,[6] length of the upper leg,[7] circumference of thigh,[7] circumference of the upper arm,[7–9] total skin-fold thickness[1 3] and skin-fold thicknesses of the lower limbs.[10 11]

The length of the running performance seems to influence the outcome. Some of these parameters are found in middle-distance runners,[2 4 5 7 10] others in marathon runners[3 12 13] and ultra-endurance runners.[8 9]

Runners over different distances need to train differently. Runners of middle distance and marathon are rather fast compared to ultra-endurance runners. Therefore, training for these different distances might also be different.

The aim of the present study was to evaluate in ultra-endurance runners in a 24-h run whether anthropometric parameters, training parameters or race history are of more importance regarding race success.

PARTICIPANTS AND METHODS

Participants

The organiser of the 19th edition of the 24-h run held in 2007 in Basel, Switzerland, contacted all participants of the race by a separate newsletter, 3 months before the race, in which they were asked to participate in the study. Eighty-six male Caucasian ultra-runners intended to start and 22 athletes were interested in our investigation. They all gave their informed written consent in accordance with the guidelines established by the Institutional Ethics Committee. No inclusion/exclusion criteria for the participants were used. Fifteen athletes (mean (SD) 46.7 (5.8 years), 71.1 (6.8 kg) body weight, 1.76 (0.07 m) body height and a body mass index of 23.1 (1.84 kg/m^2)) finished the 24-h run without a break. The other runners dropped out because of medical problems and did not finish the race. The training and race history of the finishers is presented in table 1. All participants had finished at least nine marathons (average 35 (22)) and 11 participants had already finished at least one 24-h run.

The race

The 19th edition of the 24-h run in Basel took place on 12 and 13 May 2007. Starting at noon on 12 May, runners from all over Europe performed as many laps as possible on a flat course. Each lap of 1141.86 m was counted by a personal lap counter for each runner. The weather was fine and dry. At the start, the temperature was 21°C with a cloudy sky. In the afternoon, the temperature rose to 27°C and dropped to 10°C in the night. During the night, the track was completely illuminated. After sunrise on 13 May, the temperature rose rapidly over 20°C and reached 31°C by noon. The athletes had the opportunity to take food and beverages from an abundant buffet provided by the organiser as well as their own food from their own support crews.

Anthropometrical measurements

Body mass was measured with the bioelectrical impedance (BIA) balance Tanita BC-545 (Tanita Corporation of America, Arlington Heights, Illinois, USA) to the nearest 0.1 kg. At the largest circumference points the upper arm, thigh and calf were measured to the nearest 0.1 cm. At the thigh,

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Table 1 Anthropometric parameters of the successful finishers

Parameter	Pre-race*	r^2
Age (years)	46.7 (5.8)	0.00
Body height (cm)	176 (7)	0.02
Body mass (kg)	71.1 (6.8)	0.11
Length of leg (cm)	86.9 (3.4)	0.01
C upper arm (cm)	29.0 (1.9)	0.00
C thigh (cm)	53.4 (3.2)	0.03
C calf (cm)	38.1 (2.5)	0.06
SF pectoral (mm)	5.8 (2.7)	0.09
SF axillar (mm)	6.6 (2.1)	0.12
SF triceps (mm)	7.9 (2.2)	0.07
SF subscapular (mm)	8.9 (2.4)	0.01
SF abdominal (mm)	15.6 (7.9)	0.07
SF suprailiacal (mm)	11.3 (5.1)	0.06
SF thigh (mm)	9.4 (4.6)	0.02
SF calf (mm)	6.9 (3.1)	0.00
BMI (kg/m^2)	23.1 (1.8)	0.10
SM (kg)	37.8 (3.9)	0.12
%BF	14.4 (3.5)	0.06

%BF, percentage of body fat; BMI, body mass index; C, circumference; SF, skin-fold thickness; SM, skeletal muscle mass.
Training properties of the athletes before the start of the race and the square correlation coefficient with total race time.
*Results are presented as mean (SD).

circumference was determined 20 cm above the upper pole of the patella. Every anthropometric measurement was taken by the same person three times and then the mean value was used for calculation. Skin-fold thicknesses of chest, midaxillary (vertical), triceps, subscapular, abdominal (vertical), suprailiac (at anterior axillary), thigh and calf were measured with a skin-fold calliper (GPM-Hautfaltenmessgerät, Siber & Hegner, Zurich, Switzerland) to the nearest 0.2 mm at the right side, according to Lee *et al*.[14] Skeletal muscle mass was calculated using the following formula: $SM = Ht \times (0.00744 \times CAG^2 + 0.00088 \times CTG^2 + 0.00441 \times CCG^2) + 2.4 \times sex - 0.048 \times age + race + 7.8$, where Ht = height, CAG = skin-fold-corrected upper arm girth, CTG = skin-fold-corrected thigh girth, CCG = skin-fold-corrected calf girth, sex = 1 for male, race = 0 for white, according to Lee *et al*.[14] The percentage of body fat was calculated using the following formula: $\%BF = 0.465 + 0.180(\Sigma 7SF) - 0.0002406(\Sigma 7SF)^2 + 0.0661(age)$, where $\Sigma 7SF$ = sum of skin-fold thickness of chest, midaxillary, triceps, subscapular, abdomen, suprailiac and thigh mean, according to Ball *et al*.[15]

Statistical analysis

Statistical analysis was performed with the R software package.[16] Spearman's correlation was used to correlate the reached distance with the directly measured (body mass, skin-fold thickness and circumferences of thigh, calf and upper arm) and calculated parameters (BMI, percentage of body fat, skeletal muscle mass) during the race. A non-parametric method was used, as not all parameters are ideally normally distributed. We did not correct for multiple statistical comparisons because our study had to be an exploratory investigation and not one in which specific hypotheses were tested on the basis of pre-existing data. For all statistical tests, significance was set at a level of 0.05.

RESULTS

The runners achieved an average performance of 180.7 (29.4 km), varying from 136 to 225 km. No significant association ($p>0.05$) was found between the reached distance and the anthropometric properties (table 1).

There was also no significant association between the reached distance with the weekly training hours, running years, the number of finished marathons and the number of finished 24-h runs (table 2).

Figure 1 shows the pairwise relationship among the reached distance, the best personal 24-h run distance and the personal best marathon time. The reached distance in the actual 24-h run is significantly ($p<0.05$) positively associated with the personal best marathon performance ($r^2 = 0.40$) and the personal best 24-h run distance ($r^2 = 0.58$). Furthermore, the personal best marathon performance is highly significantly and positively associated ($p<0.01$) with the best personal 24-h run distance ($r^2 = 0.76$).

DISCUSSION

Our athletes achieved a performance of 180.7 (29.4) km, which is better than the 169 (6 km) in the study of Sagnol *et al*[17] and 158.6 (26.8 km) in the study of Wu *et al*[18] in another 24-h run. We therefore presume that our athletes achieved a good performance in this race and that our data can be used for scientific evaluation. The main finding of this present investigation is the fact that anthropometric parameters are not associated with race performance, but an association with the personal best time in marathon running exists.

What parameters have an effect on marathon performance?

As fig 1 shows, performance in the actual race is associated with personal best marathon time for all participants and personal best performance in a 24-h run for those 11 participants who already have performed a 24-h run. In addition, the personal best marathon and personal best performance in a 24-h run also shows an association. In contrast, weekly training volume, years of running and number of finished marathons as well as finished 24-h runs shows no association with actual race performance (table 2). From these findings, we would deduce that a fast marathon runner should be able to reach a high number of kilometres in a 24-h run. We should therefore ask which factors have an effect on marathon performance. Predictors of competitive performances over marathon distance are BMI,[6] body fat,[6] the number of sessions per week,[12] weekly training distance,[19 20] longest and shortest training distance per week,[20] running velocity in training,[19] race time at 10 or 21.1 km[21] and Vo_2max and Vo_2peak, respectively.[3 19 22 23] In contrast, Hagan *et al*[6] found no relationship between Vo_2max and marathon performances. This was likely due to the sex difference as they investigated female runners.

Table 2 Training and race history of the successful finishers

Parameter	Pre-race	r^2
Training volume (h/week)	10.6 (3.5)	0.01
Training volume (km/week)	98.8 (31.8)	0.05
Years of competitive running	12.8 (6.7)	0.13
Number of finished marathons	35.2 (22.7)	0.09
Personal best in marathon (min)	183 (21)	0.40*
Number of finished 24-h runs	5.9 (8.0)	0.17
Personal best in 24-h run (km)	185.7 (28.2), n = 11, 4 participants had not finished a 24-h run before	0.58*

Training properties of the athletes (n = 15) before the start of the race and the square correlation coefficient with race performance. Results are presented as mean (SD).
*Statistically significant correlations, $p<0.05$.

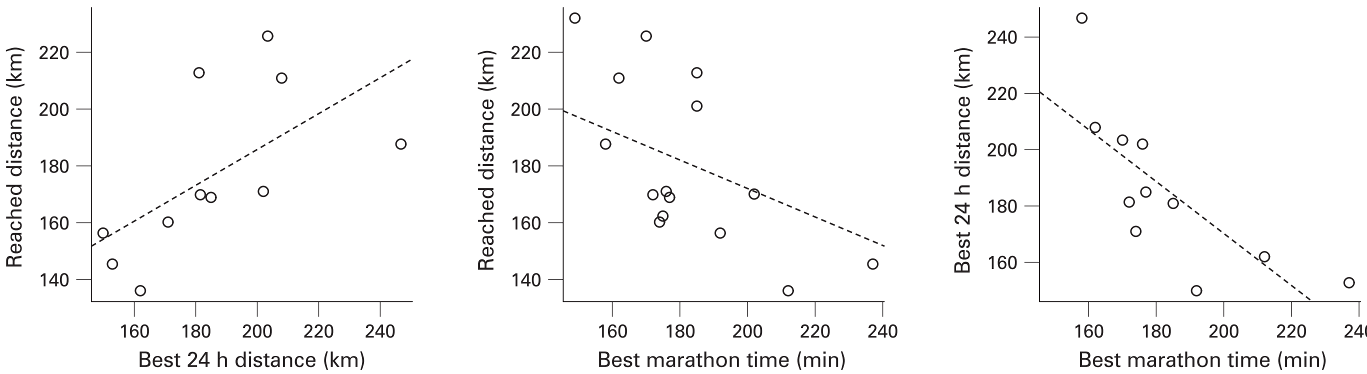

Figure 1 Pairwise relationships among the reached distance (n = 15), the best personal 24-h run distance (n = 11) and the personal best marathon time (n = 15).

Training volume and effect on marathon performance

According to our results, weekly training volume in hours and kilometres and training history with number of years competing as well as number of finished marathons and finished 24-h runs seem to have no effect on race performance (table 2). This is in contrast to the findings in literature. Training parameters seem to be of more importance than anthropometric measures in the prediction of performance in runners.[1 3 12 19 22] In marathon finishers, the longest mileage covered per training session is the best predictor for a successful completion of a marathon.[20] Scrimgeour *et al* found that runners training more than 100 km/week have significantly faster race times from 10 to 90 km than athletes covering less than 100 km.[24] However, training volume seems to have clear limits. There exists an upper limit in training volume above which there are no more improvements,[25] but some of our results (table 2) seem to be in accordance with the findings of Hagan *et al*.[3 6] Parameters such as previously completed marathons,[6] workout days,[6] total workouts,[6] total kilometres,[3] total workout days,[3] mean kilometres per workout,[3 6] total training minutes,[6] maximal kilometres of running per week,[6] mean kilometres per week[6] and mean kilometres per day[6] seem to have no effect on marathon performance. Probably sex had an effect where training volume was without influence on performance. In one study, Hagan *et al*[6] investigated in female runners, and in another,[3] male runners. Bale *et al*[1] could demonstrate in 60 male runners that the elite runners with higher training frequency, higher weekly training volume and longer running experience have a better 10-km performance.

Training intensity

When training volume is considered, intensity should also be taken into account. We did not determine training intensity. Intensity seems to have a major effect on running performance. In particular, training intensity seems to be of importance in long-distance running. Total training spent at low intensities seems to be associated with improved performance during highly intense events.[26] Obviously, runners of distances of approximately 35 min duration should train at rather low intensity. However, in Kenyan runners, the velocity at the $\dot{V}O_2max$ is the main factor predicting 10-km performance[27] and high-intensity training contributes to a higher $\dot{V}O_2max$.[27 28] Scott and Houmard[29] found that peak running velocity is highly predictive of distance running performance in highly trained endurance runners. In literature, there are some interesting findings about intensity in training and marathon performance.

Noakes *et al*[21] demonstrated no association of peak treadmill running velocity as predictor of performance in marathon specialists, but did in ultra-marathon specialists. Sex might also be of importance. Hagan *et al*[6] found no effect of training pace on marathon performances in female runners. In novice marathon runners, long slow-distance training has the same effect on marathon performances as intense training.[30]

Circumference of limbs

In two recent studies,[8 9] we found a positive association with upper arm circumference and performance in a multistage ultra-endurance run, and Tanaka and Matsuura[7] found that thigh girth was best related to performances over 800, 1500 and 5000 m, while upper arm girth was related to 10 000-m performances. Unfortunately, in this present investigation, we found no association between upper arm circumference and race performance over a 24-h run. Also, the quotient upper arm circumference and thigh circumference was not associated with performance. Probably a run over 1200 km[8] and 338 km[9] needs a different body composition to running approximately 180 km.

CONCLUSIONS

Anthropometry and training volume does not seem to have a major effect on race performance in a 24-h run. Instead, a fast personal best marathon time seems to be the only positive association with race performance in a 24-h run. In future studies, training intensity and running economy in runners over marathon and ultra-marathon distances should be further investigated.

What is already known on this topic

Training parameters seem to be of more importance than anthropometric measures in the prediction of performance in runners.

What this study adds

In ultra-runners at a 24-h run, neither training volume nor anthropometry was associated, rather, personal best time in marathon running.

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Competing interests: None.

Ethics approval: Informed written consent in accordance with the guidelines established by the Institutional Ethics Committee was obtained.

Patient consent: Obtained.

REFERENCES

1. **Bale P,** Bradbury D, Colley E. Anthropometric and training variables related to 10 km running performance. *Br J Sports Med* 1986;**20**:170–3.
2. **Coetzer P,** Noakes TD, Sanders B, *et al*. Superior fatigue resistance of elite black South African distance runners. *J Appl Physiol* 1993;**75**:1822–7.
3. **Hagan RD,** Smith MG, Gettman LR. Marathon performance in relation to maximal aerobic power and training indices. *Med Sci Sports Exerc* 1981;**13**:185–9.
4. **Kenney WL.** Hodgson JL. Variables predictive of performance in elite middle-distance runners. *Br J Sports Med* 1985;**19**:207–9.
5. **Maldonado S,** Mujika I, Padilla S. Influence of body mass and height on the energy cost of running in highly trained middle- and long-distance runners. *Int J Sports Med* 2002;**23**:268–72.
6. **Hagan RD,** Upton SJ, Duncan JJ, *et al*. Marathon performance in relation to maximal aerobic power and training indices in female distance runners. *Br J Sports Med* 1987;**21**:3–7.
7. **Tanaka K,** Matsuura Y. A multivariate analysis of the role of certain anthropometric and physiological attributes in distance running. *Ann Hum Biol* 1982;**9**:473–82.
8. **Knechtle B,** Knechtle P, Schulze I, *et al*. Upper arm circumference is associated with race performance in ultra-endurance runners. *Br J Sports Med*. Published Online First 28 June 2007. doi:10.1136/bjsm.2007.038570.
9. **Knechtle B,** Duff B, Welzel U, *et al*. Body mass and circumference of upper arm are associated with race performance in ultra-endurance runners in a multi-stage race—the Isarrun 2006. *Res Q Exerc Sport* 2008. In press.
10. **Arrese AL,** Ostariz ES. Skinfold thicknesses associated with distance running performance in highly trained runners. *J Sports Sci* 2006;**24**:69–76.
11. **Legaz A,** Eston R. Changes in performance, skinfold thicknesses, and fat patterning after three years of intense athletic conditioning in high level runners. *Br J Sports Med* 2005;**39**:851–6.
12. **Bale P,** Rowell S, Colley E. Anthropometric and training characteristics of female marathon runners as determinants of distance running performance. *J Sports Sci* 1985;**3**:115–26.
13. **Legaz Arrese A,** Gonzalez Badillo JJ, Serrano Ostariz E. Differences in skinfold thicknesses and fat distribution among top-class runners. *J Sports Med Phys Fitness* 2005;**45**:512–17.
14. **Lee RC,** Wang Z, Heo M, *et al*. Total-body skeletal muscle mass: development and cross-validation of anthropometric prediction models. *Am J Clin Nutr* 2000;**72**:796–803.
15. **Ball SD,** Altena TS, Swan PD. Comparison of anthropometry to DXA: a new prediction equation for men. *Eur J Clin Nutr* 2004;**58**:1525–31.
16. **R Development Core Team**. *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing, 2007. http://www.R-project.org.
17. **Sagnol M,** Claustre J, Pequigno JM, *et al*. Catecholamines and fuels after an ultralong run: persistent changes after 24-h recovery. *Int J Sports Med* 1989;**10**:202–6.
18. **Wu HJ,** Chen KT, Shee BW, *et al*. Effects of 24 h ultra-marathon on biochemical and haematological parameters. *World J Gastroenterol* 2004;**10**:2711–14.
19. **Billat VL,** Demarle A, Slawinski J, *et al*. Physical and training characteristics of top-class marathon runners. *Med Sci Sports Exerc* 2001;**33**:2089–97.
20. **Yeung SS,** Yeung EW, Wong TW. Marathon finishers and non-finishers characteristics. A preamble to success. *J Sports Med Phys Fitness* 2001;**41**:170–6.
21. **Noakes TD,** Myburgh KH, Schall R. Peak treadmill running velocity during the Vo_2max test predicts running performance. *J Sports Sci* 1990;**8**:35–45.
22. **Christensen CL,** Ruhling RO. Physical characteristics of novice and experienced women marathon runners. *Br J Sports Med* 1983;**17**:166–71.
23. **Davies CT,** Thompson MW. Aerobic performance of female marathon and male ultramarathon athletes. *Eur J Appl Physiol* 1979;**41**:233–45.
24. **Scrimgeour AG,** Noakes TD, Adams B, *et al*. The influence of weekly training distance on fractional utilization of maximum aerobic capacity in marathon and ultramarathon runners. *Eur J Appl Physiol* 1986;**55**:202–9.
25. **Sjödin B,** Svedenhag J. Applied physiology of marathon running. *Sports Med* 1985;**2**:83–99.
26. **Esteve-Lanao J,** San Juan AF, Earnest CP, *et al*. How do endurance runners actually train? Relationship with competition performance. *Med Sci Sports Exerc* 2005;**37**:496–504.
27. **Billat V,** Lepretre PM, Heugas AM, *et al*. Training and bioenergetic characteristics in elite male and female Kenyan runners. *Med Sci Sports Exerc* 2003;**35**:297–304.
28. **Billat V,** Demarle A, Paiva M, *et al*. Effect of training on the physiological factors of performance in elite marathon runners (male and females). *Int J Sports Med* 2002;**23**:336–41.
29. **Scott BK,** Houmard JA. Peak performance velocity is highly related to distance running performance. *Int J Sports Med* 1994;**15**:504–7.
30. **Dolgener FA,** Kolkhorst FW, Whitsett DA. Long slow distance training in novice marathoners. *Res Q Exerc Sport* 1994;**65**:339–46.