Open Access Journal of Sports Medicine

Dovepress
open access to scientific and medical research

Open Access Full Text Article

ORIGINAL RESEARCH

Effects of training and anthropometric factors on marathon and 100 km ultramarathon race performance

This article was published in the following Dove Press journal:
Open Access Journal of Sports Medicine
28 April 2015

Giovanni Tanda[1]
Beat Knechtle[2,3]

[1]Polytechnic School, University of Genoa, Genoa, Italy; [2]Gesundheitszentrum St Gallen, St Gallen, [3]Institute of Primary Care, University of Zurich, Zurich, Switzerland

Background: Marathon (42 km) and 100 km ultramarathon races are increasing in popularity. The aim of the present study was to investigate the potential associations of anthropometric and training variables with performance in these long-distance running competitions.

Methods: Training and anthropometric data from a large cohort of marathoners and 100 km ultramarathoners provided the basis of this work. Correlations between training and anthropometric indices of subjects and race performance were assessed using bivariate and multiple regression analyses.

Results: A combination of volume and intensity in training was found to be suitable for prediction of marathon and 100 km ultramarathon race pace. The relative role played by these two variables was different, in that training volume was more important than training pace for the prediction of 100 km ultramarathon performance, while the opposite was found for marathon performance. Anthropometric characteristics in terms of body fat percentage negatively affected 42 km and 100 km race performance. However, when this factor was relatively low (ie, less than 15% body fat), the performance of 42 km and 100 km races could be predicted solely on the basis of training indices.

Conclusion: Mean weekly training distance run and mean training pace were key predictor variables for both marathon and 100 km ultramarathon race performance. Predictive correlations for race performance are provided for runners with a relatively low body fat percentage.

Keywords: running, performance, training indices, body fat, sports training

Introduction

The popularity of endurance running events like the marathon (42 km) and ultramarathon (typically 100 km) has increased tremendously over the last two decades.[1,2] This has generated interest in development of regression equations able to predict race performance in order to help the great mass of recreational athletes in their preparation for long-distance running competitions. It is logically assumed that a combination of physiological, anthropometric, and training factors is critical for optimal prediction of race performance.

Apart from physiological parameters, measurement of which is generally reserved for high-level distance runners, a number of anthropometric variables are related to endurance running performance, such as body mass index (BMI),[3] body fat percentage,[4,5] and the circumference of the upper arm.[6] Among these anthropometric factors, body fat percentage turned out to be the best predictor of performance in a marathon[5] and correlated significantly with ultramarathon race performance.[7] In addition to anthropometry, numerous studies have investigated the effect of

Correspondence: Beat Knechtle
Gesundheitszentrum St Gallen
26, Vadianstrasse, 9001 St Gallen
Switzerland
Tel +41 71 226 8282
Fax +41 71 226 8272
Email beat.knechtle@hispeed.ch

submit your manuscript | www.dovepress.com
Dovepress
http://dx.doi.org/10.2147/OAJSM.S80637

training characteristics on performance in long-distance competitions.[5,7–12] During training ultramarathoners run at a significantly lower velocity than marathoners, but invest in more hours of training per week, and with a markedly larger training volume.[13,14] Despite these differences, a positive association between training indices (ie, training volume and intensity) and race performance has been demonstrated for both marathoners[11] and ultramarathoners.[7]

The aim of the present study was two fold. First, potential associations of anthropometric and training variables with race pace (and thus race time) in marathoners and 100 km ultramarathoners were investigated using bivariate analyses; the relative role played by main predictor variables during the two different competitions was then compared and discussed. Second, a relationship for prediction of 100 km race performance, the structure of which was similar to that previously developed by the authors for the prediction of 42 km race performance,[11,12] was developed by multivariate regression analysis. The study used as input data the training and anthropometric characteristics of marathoners and 100 km ultramarathoners provided by Tanda,[11] Barandun et al,[5] and Knechtle et al.[7]

Materials and methods

Data sampling

Training and pre-race anthropometric data for a number of athletes participating in marathon (42 km) and ultramarathon (100 km) races, collected by Tanda,[11] Barandun et al,[5] and Knechtle et al,[7] were processed in this study in order to investigate their possible association with race performance and to infer the relative role played in these two long-distance competitions. Among the numerous variables available for the sample groups included in each database, attention was focused on training volume and intensity (ie, training factors) and on BMI and body fat percentage (ie, anthropometric factors).

Ethics

All procedures used in the study were approved by the institutional review board of Kanton St Gallen, Switzerland. All runners were informed of the procedures and gave their informed written consent to participate in the study.

Subjects

Tanda collected training data and data on the pre-race BMI of marathoners.[11] The training data, recorded during workouts on track or Global Positioning System (GPS)-assisted, were accumulated over an 8-week period preceding the race for a relatively large sample group (n=46, age 28–54 years, mean 42.8 years) of athletes running a marathon between 167 and 216 minutes. The subjects did not participate in the same race, but ran different marathons with the same level of difficulty and similar weather conditions; moreover, they were requested to keep a regular pace during the race (ie, with a difference between first half and second half times of less than 4 minutes) at the highest intensity in line with their training level.

Barandun et al collected training and anthropometric characteristics for 126 male marathoners (age 18–72 years, mean 42.8 years) participating in different editions (2010 and 2011) of the Basel Marathon held in Switzerland.[5] Training data were self-recorded by the athletes over a 3-month period before the race and self-reported by returning a questionnaire; anthropometric data were measured the day before the race.

Training and pre-race anthropometric data for 169 males (age 18–74 years, mean 46.5 years) participating in ultrarun (100 km) races were collected by Knechtle et al in four consecutive years (from 2007 to 2010) of the 100 km Lauf Biel held in Switzerland.[7] Training data were obtained according to the same procedure followed by Barandun et al,[5] and anthropometric data were measured the day before the race.

The main anthropometric and training characteristics of all the subjects, as well as the race performance (ie, finishing time and mean race pace), are listed in Table 1.

Table 1 Training and anthropometric variables of the subjects and their race performance (results are presented as the mean ± standard deviation)

	Variable	Result
Data for 42 km runners from Tanda[11] n=46	Mean training distance run per week (km/week)*	65.9±15.9
	Mean training pace (sec/km)*	285±18
	Body mass index (kg/m²)°	21.7±1.3
	Race finishing time (minutes)	191±12
	Mean race pace (sec/km)	272±18
Data for 42 km runners from Barandun et al[5] n=126	Mean training distance run per week (km/week)**	44.7±24.7
	Mean training pace (sec/km)**	330±41
	Body mass index (kg/m²)°	23.4±2.2
	Body fat percentage (%)°	16.3±3.6
	Race finishing time (minutes)	232±32
	Mean race pace (sec/km)	330±45
Data for 100 km ultrarunners from Knechtle et al[7] n=169	Mean training distance run per week (km/week)**	70.3±27.6
	Mean training pace (sec/km)**	366±98
	Body mass index (kg/m²)°	23.4±2.2
	Body fat percentage (%)°	16.1±4.3
	Race finishing time (minutes)	713±131
	Mean race pace (sec/km)	428±78

Notes: *Averaged over an 8-week period prior to the race; **averaged over a 3-month period prior to the race; °evaluated the day before the race or immediately before the race start.

Design and procedures

High quality of self-reported training variables is crucial for reliable statistical analysis of data and to assess for a possible association with race performance time. At the same time, only data from subjects whose race performance was characterized by a regular pace during the race were deemed to be significant in a statistical analysis aimed at finding a correlation between race performance and training/anthropometric factors.

After refinement of the input data, as described in the two following subsections, each input database was processed in order to infer a possible association of training and anthropometric indices of subjects with race performance by using bivariate and multiple regression analyses, as explained in the final subsection.

Training and anthropometric data for marathoners

In order to make the sample group included in the study by Barandun et al[5] qualitatively similar to that considered by Tanda,[11] some data exclusion criteria were implemented by Tanda and Knechtle;[12] for instance, subjects who did not run their marathon race at a regular pace were eliminated from the sample group. Refinement of the data from Barandun et al[5] by Tanda and Knechtle[12] reduced the database to n=25 for the relationship between marathon performance time and training indices and to n=52 for the relationship between marathon performance time and anthropometric indices.

Training and anthropometric data for ultramarathoners

Knechtle et al processed a very large data sample (n=169) of runners providing self-recorded training data.[7] Many of them did not run the ultrarace at a regular pace (ie, alternating walking and running), making the race pace highly unpredictable. For the above-mentioned reasons, the n=169 database was refined in the present study according to the procedure previously described by Tanda and Knechtle.[12] The major exclusion criterion was to eliminate those athletes from the database who had run the 100 km race with variations in their race velocity greater than ±15% of the mean race velocity. This check was performed by processing the split times for four different segments of the race reported on the official 100 km Lauf Biel website. After refinement of the data, the sample data for the ultramarathoners was reduced to n=77 for the relationship between 100 km race time and training indices and to n=135 for the relationship between 100 km race time and anthropometric indices.

Statistical analysis

The correlations between training/anthropometric indices for subjects and their race performance were assessed by regression analysis. For this purpose, commercial software package CurveExpert version 1.3 was used. The curves of best fit according to different shapes (eg, linear and nonlinear, such as polynomial, exponential, and power) were identified to correlate the training and anthropometric variables with the effective race pace recorded for the athletes included in each database. To evaluate the accuracy of a given regression curve, the standard error of estimate (SEE) and the correlation coefficient r were considered. For a perfect fit, the SEE is expected to approach zero and the correlation coefficient r to approach unity. Conversely, too large values of SEE or values of r relatively far from unity are considered to indicate poor quality of the correlation.

The best predictive factors for race pace were then identified from a comparative analysis on the basis of the respective values of SEE and r.

Finally, a multiple nonlinear regression analysis was performed using a custom-made iterative algorithm to determine the relationship giving the 100 km race pace as a function of the best predictive factors. A similar approach has been adopted by the authors to develop predictive correlations for 42 km race performance.[11,12] The quality of the predictive relationship developed for 100 km race performance was assessed using plots giving the predicted race pace (and the deviation of predicted from measured race pace) versus the measured race pace. Predicted and measured data for the 42 km race[11,12] are reported in the same plots to enable a comparison between analyses conducted for marathoners and ultramarathoners.

Results

Previous analyses presented in Knechtle et al,[7] Tanda,[11] and Tanda and Knechtle[12] indicated that the mean training distance per week K and the mean training pace P (or velocity V), recorded over a given period (ie, 8 weeks or 3 months) before the race, highly correlated with race finishing time (or race pace P_{race}), with pre-race body fat percentage (%BF) emerging as the main anthropometric factor affecting race performance. Thus, bivariate analyses were conducted here in order to find a possible association of K, P, and %BF with race pace P_{race}.

Figure 1 shows the relationship between race pace P_{race} (for 42 km and 100 km races) and the mean weekly training distance K. For marathoners, K was highly correlated with P_{race} by means of a curve in the form of an exponential decay (correlation coefficient r=0.68). For ultramarathoners, the correlation between K and P_{race} was weak; a high degree of correlation (r=0.73) was found only when data for athletes with %BF <15% were considered.

The relationship between training running pace P and race running pace P_{race} is shown in Figure 2. Data for marathoners and 100 km ultramarathoners were linearly correlated, but the quality of the correlation was higher for the 42 km data (r=0.87) than for the 100 km data (r=0.55). The quality of correlation between P_{race} and P did not improve for the 100 km data when only athletes with %BF <15% were taken into account. During the marathon, race velocity typically exceeded training velocity (ie, P_{race}<P); the opposite, however, was found for the 100 km ultramarathon.

The race pace taken during the 42 km and 100 km races is plotted against %BF in Figure 3. Race pace tended to increase linearly with %BF for marathoners and ultramarathoners, but the correlation coefficients were not high (r=0.60 for 42 km and r=0.51 for 100 km, respectively). If only data featuring %BF <15% were considered, no association between %BF and race pace was found for 42 km or 100 km races.

A multiple nonlinear regression analysis made it possible to show the development of a relationship giving the predicted race pace P^*_{race} for the 100 km ultrarunners as a function of training intensity (P) and volume (K):

$$P^*_{race}\ (\text{sec/km}) = 139.8 + 372.2\ \exp[-0.0086\ K\ (\text{km/week})] + 0.15\ P\ (\text{sec/km}) \qquad (1)$$

Equation 1 was obtained by processing the training data for the male ultramarathoners having a %BF <15% (n=38, finishing time 446–833 minutes). The SEE of Equation 1 is 38 sec/km, with a correlation coefficient r=0.74. Based on the considerations outlined in the comments to Figures 1 and 3, although a generalized reduction in race velocity (and thus an increase in race pace) was observed as %BF increased, any attempt to include the effect of %BF in the analysis led to a correlation characterized by a larger SEE and a lower value of r. It is speculated that a fairly reliable predictive correlation

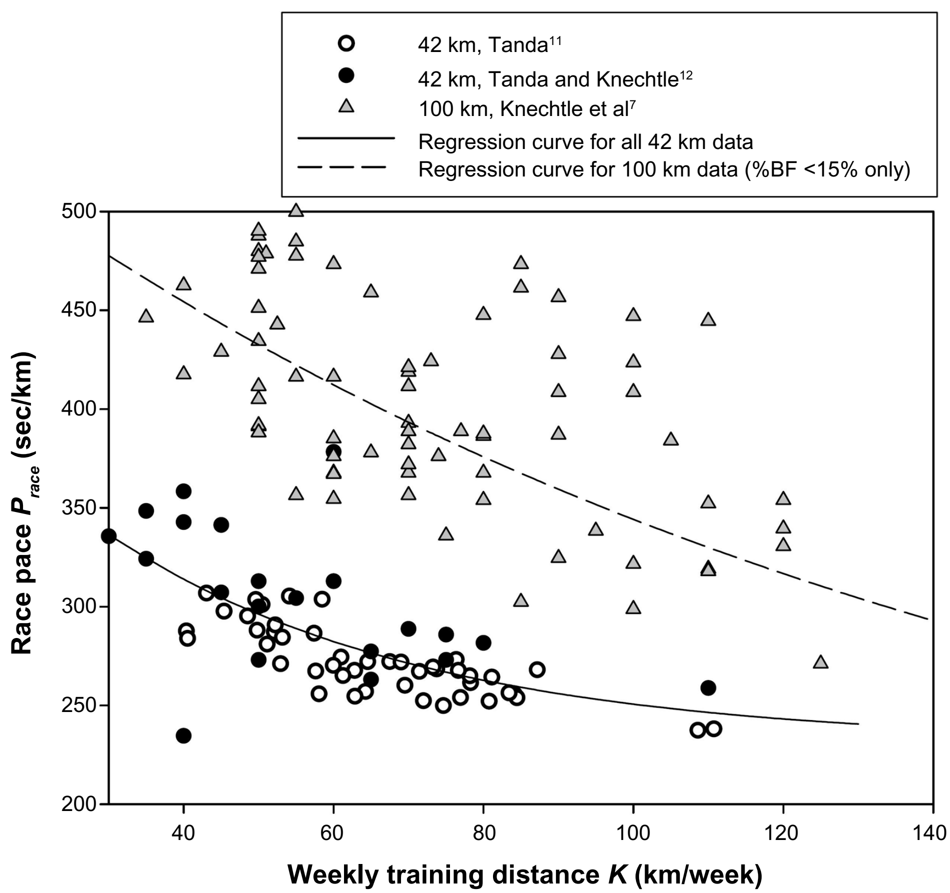

Figure 1 Marathon and ultramarathon (100 km) race pace versus weekly training distance run.
Abbreviation: %BF, percentage body fat.

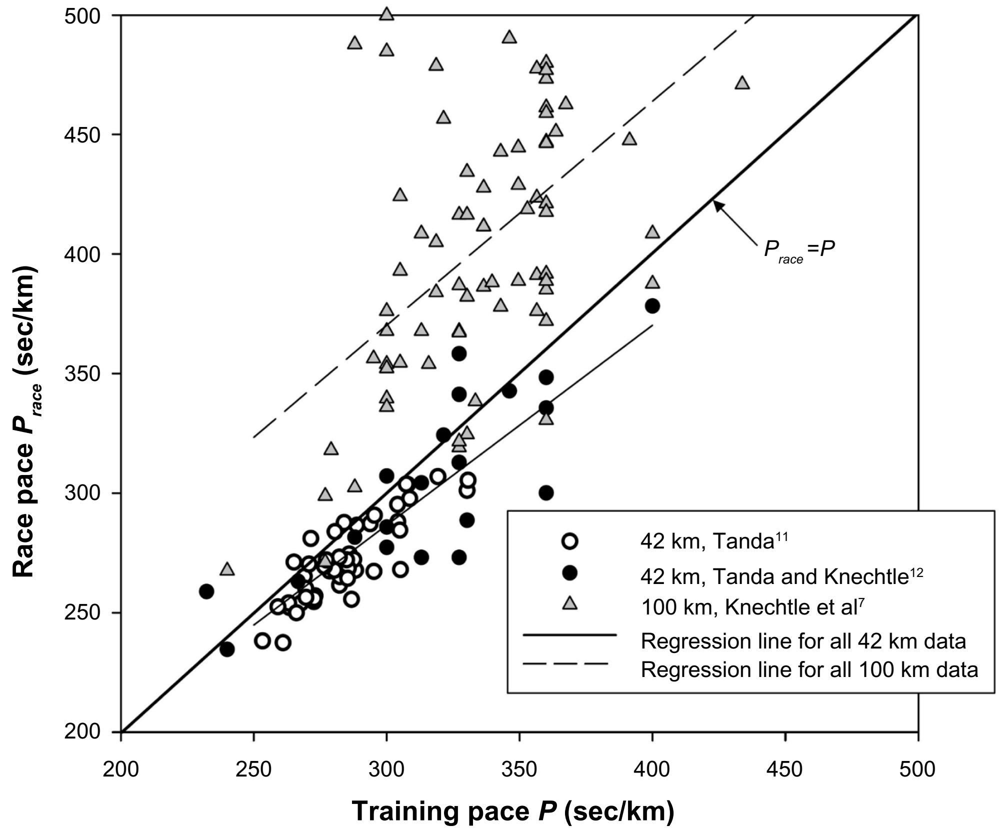

Figure 2 Marathon and ultramarathon (100 km) race pace versus mean training pace.

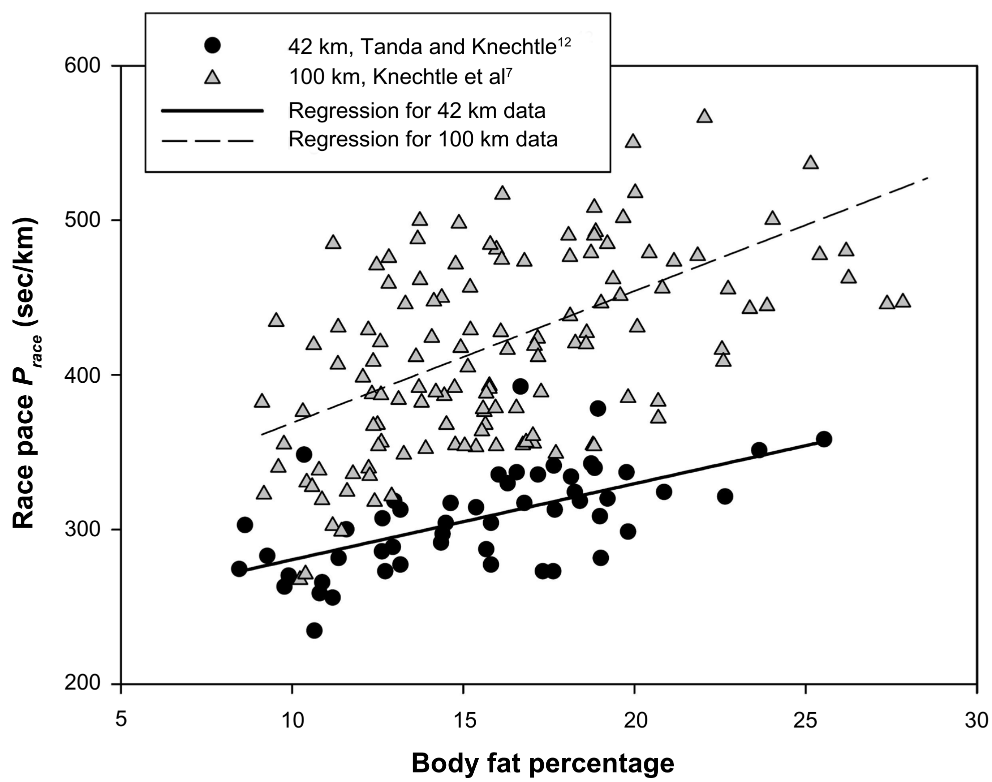

Figure 3 Marathon and ultramarathon (100 km) race pace versus pre-race body fat percentage.

for the ultra-endurance run performance can be successfully obtained only for athletes having a low %BF.

Discussion

Multiple regression analyses conducted by Tanda[11] and Tanda and Knechtle[12] have yielded correlations giving the predicted marathon pace P^*_{race} versus training (K and P) and anthropometric (%BF) indices:

$$P^*_{race}\ \text{(sec/km)} = 17.1 + 140.0\ \exp[-0.0053\ K\ \text{(km/week)}] + 0.55\ P\ \text{(sec/km)},\ \text{Tanda}^{11} \quad (2)$$

SEE =5.7 sec/km, r=0.94, n=46.

$$P^*_{race}\ \text{(sec/km)} = 15.68 + 140.0\ \exp[-0.0053\ K\ \text{(km/week)}] + 0.55\ P\ \text{(sec/km)} + 0.142\ \exp[0.23\ \%\text{BF}\ (\%)]$$

Tanda and Knechtle[12] (3)

SEE =20 sec/km, r=0.81, n=25.

Both correlations for prediction of marathon pace included the effects of training indices K and P. Equation 2 does not take into account the effect of the anthropometric characteristics of the subjects. The pre-race BMI was recorded by Tanda,[11] but no significant association of BMI with marathon performance was observed; it was only noticed that when the sample of runners with a BMI $<$23 was considered (n=37), where the SEE of Equation 2 dropped from 5.7 sec/km to 5.1 sec/km. The range of marathon performance time over which Equation 2 was tested was 167–216 minutes.

Equation 3 gives the marathon pace as a function of training (K and P) and anthropometric (%BF) indices. It covers a larger variability in marathon performance time (from 165 to 266 minutes) but is characterized by a larger SEE with respect to Equation 2. When %BF was $<$15%, Equations 2 and 3 are in close agreement, with differences in the predicted marathon pace within the 0–3 (sec/km) range (ie, less than about 2 minutes in terms of finishing time); it is argued that when %BF is lower than a critical value, marathon performance depends only on training indices. When body fat percentage exceeds 15%, it negatively affected race pace, as found by Tanda and Knechtle.[12]

A comparison of Equation 1 obtained for 100 km ultrarunners and Equations 2 and 3 developed for the 42 km race is reported in Figure 4; only data provided by runners having %BF $<$15% were considered (sample data from Tanda[11] was restricted to subjects with BMI $<$23). Inspection of the figure reveals that race pace predicted by Equations 2 and 3, giving almost coincident results for %BF $<$15%, are very close to the line of perfect agreement, especially when the sample group database from Tanda[11] was used. Figure 5 shows the deviation of the predicted race pace from the measured race pace for all relationships and competitions (42 km and 100 km). The predicted marathon pace evaluated according to the data from Tanda and Knechtle[12] has a larger scatter around the line of perfect agreement, and this is probably due to the poorer quality (with respect to data from Tanda[11]) of self-reported training data, to the longer period of the training diary, and to the wider range of race finishing times.

Figures 4 and 5 show that race pace values for the 100 km ultramarathon cover a larger range with respect to that for the 42 km race, with velocities taken by the ultramarathoners being typically lower than those required by the sample group to run the marathon. Moreover, the deviations of predicted race pace from measured race pace were significantly larger than those obtained for the 42 km race; this finding suggests that prediction of 100 km race performance from Equation 1 should be done with caution. As previously mentioned, the predictive relationship for 100 km race pace (Equation 1) was developed by considering only subjects with %BF $<$15%. Although the anthropometric characteristics of male ultramarathoners can vary widely, as pointed out by Hoffman,[3,4] a relatively large mass of body fat does not preclude finishing the race, but probably precludes the possibility of reliable prediction of race finishing time. Moreover, it is worthy of note that Equation 1 was developed by processing data from a sample group running the same 100 km ultramarathon in different years. Given that 100 km races are characterized by a geographic terrain (ie, road or trail, flat or with several climbs and descents) that often differs markedly from race to race, the coefficients (not variables) in Equation 1 may change when a 100 km ultramarathon different from the 100 km Biel race is considered.

%BF $<$15% turned out not to be correlated with the ultrarun race pace, this last only being affected by training volume and intensity, as found for marathoners with low %BF values. In particular, the weekly training distance was the main predictor variable. However, the opposite was found by Tanda[11] for marathoners whose finishing time (or race pace) prediction was mainly affected by training intensity (mean training pace) rather than training volume (mean weekly training distance). This finding is in line with an observation by Rüst et al.[14]

Practical applications

Athletes and coaches should be aware that there is a significant association between race performance and training

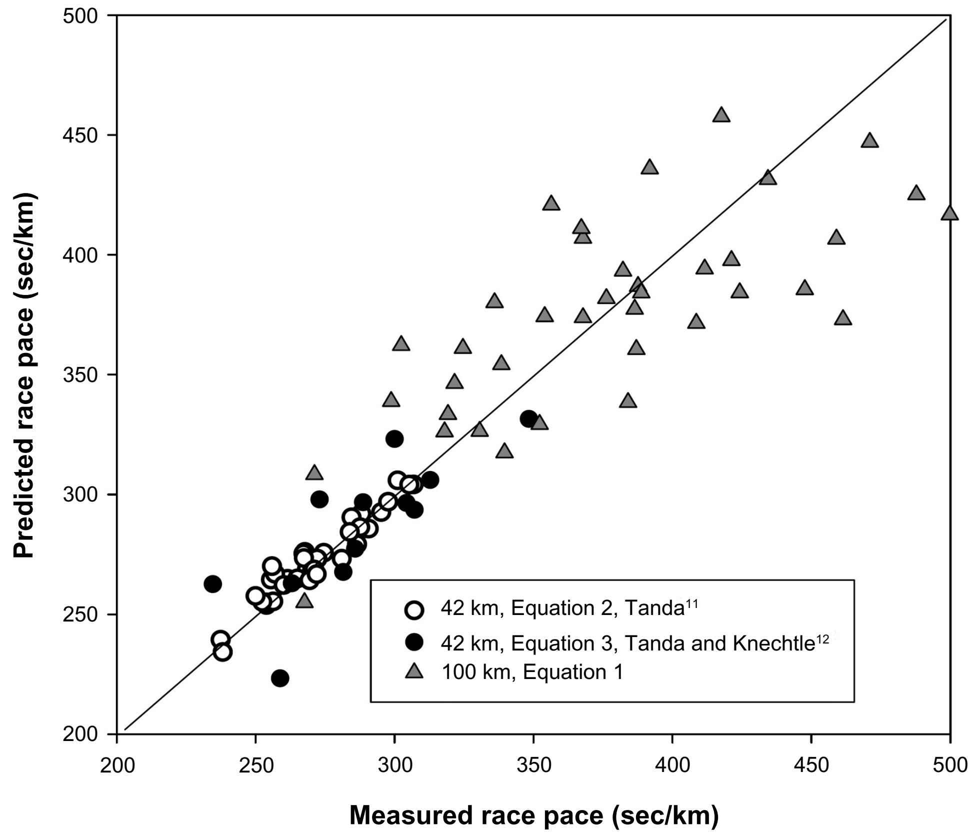

Figure 4 Marathon and ultramarathon (100 km) pace: predicted values against measured values. Solid line indicates perfect agreement.

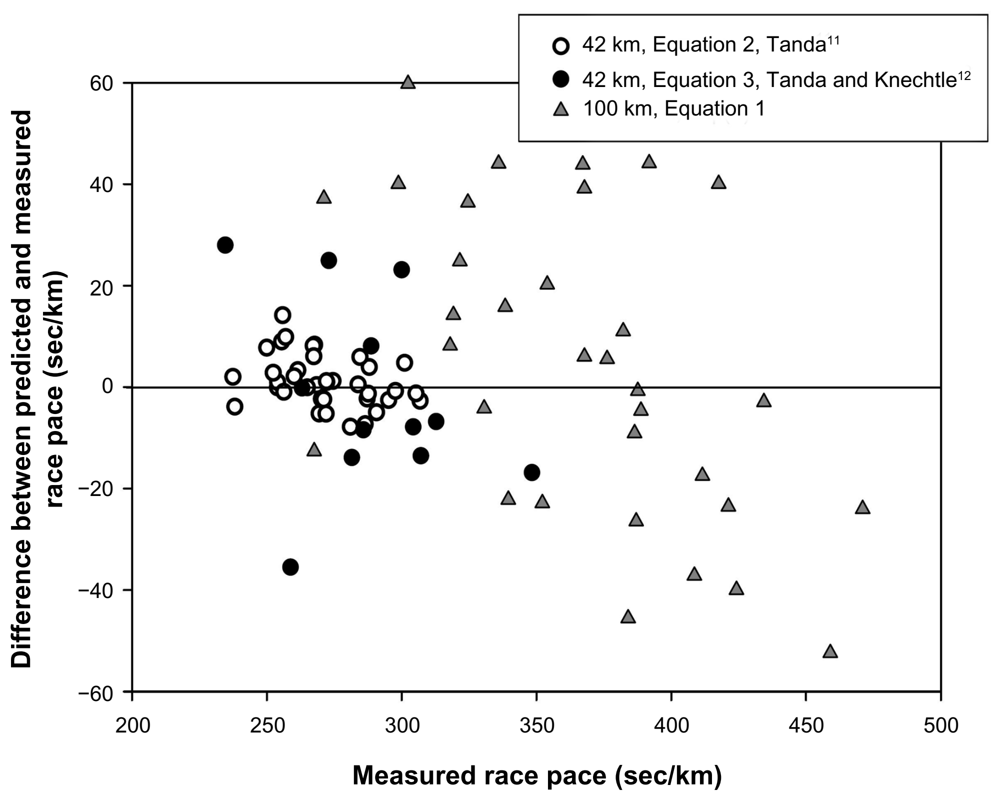

Figure 5 Marathon and ultramarathon (100 km) pace: difference between predicted values and measured values against measured values. Solid line indicates perfect agreement.

indices, such as training intensity and weekly running volume, in long-distance running races. Training speed (or pace) emerged as the main variable predicting 42 km race performance, while training volume was found to be the main factor predicting 100 km race time. Moreover, anthropometric attributes seemed to be of less importance for prediction of 42 km and 100 km race pace if the subjects have a relatively low level of body fat. Given the increasing popularity of recreational running, a method of predicting performance based on training indices may be an attractive and inexpensive alternative to extensive metabolic testing. The predictive correlations tested for the 42 km race pace and the equation developed in this study for 100 km race pace prediction, could be expanded for use in a greater population of runners, but in the meantime provide useful and reliable support for athletes preparing for a 42 km or 100 km competition.

Conclusion

A comparative study of the effects of training and anthropometric characteristics on marathon and ultramarathon performance was performed. Training and anthropometric data for sample groups of marathoners and ultramarathoners were processed. The main findings can be summarized as follows: mean weekly training distance run K and mean training pace P were the key predictor variables for both marathon and ultramarathon race times; the anthropometric characteristics in terms of %BF negatively affected 42 km and 100 km race times; however, when %BF was lower than a critical value of 15%, %BF turned out not to be significantly correlated with race performance; bivariate analysis showed that marathon race pace was more significantly correlated with training pace than training volume; conversely, ultramarathon pace was mainly associated with training volume and less with training pace for subjects having a relatively low level of body fat; and marathon and ultramarathon race performance can be predicted on the basis of the sole training indices for runners with %BF $<$15%, although accuracy is greater for the 42 km race than for the 100 km race.

Disclosure

The authors report no conflicts of interest in this work.

References

1. Mathews SC, Narotsky DL, Bernholt DL, et al. Mortality among marathon runners in the United States, 2000–2009. *Am Sports Med*. 2012;40:1495–1500.
2. Cejka N, Rüst CA, Lepers R, Onywera V, Rosemann T, Knechtle B. Participation and performance trends in 100 km ultramarathons worldwide. *J Sports Sci*. 2014;32:354–366.
3. Hoffman MD. Anthropometric characteristics of ultramarathoners. *Int J Sports Med*. 2008;29:808–811.
4. Hoffman MD, Lebus DK, Ganong AC, Casazza GA, Van Loan M. Body composition of 161 km ultramarathoners. *Int J Sports Med*. 2010;31:106–109.
5. Barandun U, Knechtle B, Knechtle P, et al. Running speed during training and percent body fat predict race time in recreational male marathoners. *Open Access J Sports Med*. 2012;3:51–58.
6. Knechtle B, Knechtle P, Schulze I, Kohler G. Upper arm circumference is associated with race performance in ultra-endurance runners. *Br J Sports Med*. 2008;42:295–299.
7. Knechtle B, Knechtle P, Rosemann T, Lepers R. Predictor variables for a 100 km race time in male ultramarathoners. *Percept Mot Skills*. 2010;11:681–693.
8. Hagan RD, Smith MG, Gettman LR. Marathon performance in relation to maximal aerobic power and training indices. *Med Sci Sports Exerc*. 1981;3:185–189.
9. Bale P, Rowell S, Colley E. Anthropometric and training characteristics of female marathon runners as determinants of distance running performance. *J Sports Sci*. 1985;3:115–126.
10. Hagan RD, Upton SJ, Duncan JJ, Gettman LR. Marathon performance in relation to maximal aerobic power and training indices in female distance runners. *Br J Sports Med*. 1987;21:3–7.
11. Tanda G. Prediction of marathon performance time on the basis of training indices. *J Hum Sport Exerc*. 2011;6:511–520.
12. Tanda G, Knechtle B. Marathon performance in relation to body fat percentage and training indices in recreational male runners. *Open Access J Sports Med*. 2013;4:141–149.
13. Knechtle B. Ultramarathon runners: nature or nurture? *Int J Sports Physiol Perform*. 2012;7:310–312.
14. Rüst CA, Knechtle B, Knechtle P, Rosemann T. Similarities and differences in anthropometry and training between recreational male 100 km ultramarathoners and marathoners. *J Sports Sci.* 2012;30:1249–1257.