Perceptual and Motor Skills, 2010, 111, 3, 681-693.

PREDICTOR VARIABLES FOR A 100-KM RACE TIME IN MALE ULTRA-MARATHONERS[1, 2]

BEAT KNECHTLE

Gesundheitszentrum St. Gallen, Switzerland
Institute of General Practice and Health Services Research University of Zurich

PATRIZIA KNECHTLE

Gesundheitszentrum St. Gallen, Switzerland

THOMAS ROSEMANN

Institute of General Practice and Health Services Research University of Zurich

ROMUALD LEPERS

INSERM U887, Faculty of Sport Sciences, University of Burgundy

Summary.—In 169 male 100-km ultra-marathoners, the variables of anthropometry, training, and prerace experience, in order to predict race time, were investigated. In the bivariate analysis, age ($r = .24$), body mass ($r = .20$), Body Mass Index ($r = .29$), circumference of upper arm ($r = .26$), percent body fat ($r = .45$), mean weekly running hours ($r = -.21$), mean weekly running kilometers ($r = -.43$), mean speed in training ($r = -.56$), personal best time in a marathon ($r = .65$), the number of finished 100-km ultra-runs ($r = .24$), and the personal best time in a 100-km ultra-run ($r = .72$) were associated with race time. Stepwise multiple regression showed that training speed ($p < .0001$), mean weekly running kilometers ($p < .0001$), and age ($p < .0001$) were the best correlations for a 100-km race time. Performance may be predicted ($n = 169$, $r^2 = .43$) by the following equation: 100-km race time (min) = 1,085.60 − 36.26 × (training speed, km/hr.) − 1.43 × (training volume, km/wk.) + 2.50 × (age, yr.). Overall, intensity of training might be more important for a successful outcome in a 100-km race than anthropometric attributes. Motivation to train intensely for such an ultra-endurance run should be explored as this might be the key for a successful finish.

Running is a popular sports discipline and can be performed over a large range of distances (Marti, Abelin, & Minder, 1988; Nettleton & Hardey, 2006). An abundant variety of physiological, anthropometrical, and training variables seems to influence running performances, depending upon the length and duration of performance (Morgan, Martin, & Krahenbuhl, 1989; Pate, Macera, Bailey, Bartoli, & Powell, 1992; Anderson, 1996; Saunders, Pyne, Telford, & Hawley, 2004). In ultra-endurance running of

[1]Address correspondence to Beat Knechtle, M.D., Facharzt FMH für Allgemeinmedizin, Gesundheitszentrum St. Gallen, Vadianstrasse 26, 9001 St. Gallen, Switzerland or e-mail (beat.knechtle@hispeed.ch).
[2]We thank the crew of 100 km Biel for their generous support and the athletes for their promptness in collecting data. For their help in translation, we thank Matthias Knechtle, Lausanne, Switzerland, and Mary Miller from Stockton-on-Tees, Cleveland, England, crew member of an ultra-endurance support crew.

DOI 10.2466/05.25.PMS.111.6.681-693 ISSN 0031-5125

distances longer than the marathon, of 42.195 km, body mass (Knechtle, Duff, Welzel, & Kohler, 2009), Body Mass Index (Hoffman, 2008), percent body fat (Hoffman, Lebus, Ganong, Casazza, & Van Loan, 2010), and circumference of upper arm (Knechtle, Knechtle, Schulze, & Kohler, 2008; Knechtle, *et al.*, 2009) were related to finish times. However, in several studies of ultra-marathoners, anthropometric parameters were not related to performance (Knechtle, Duff, Schulze, Rosemann, & Senn, 2009; Knechtle, Wirth, Knechtle, Zimmermann, & Kohler, 2009; Knechtle, Wirth, Knechtle, & Rosemann, 2010).

In runners of distances up to the marathon distance, volume and intensity of training seemed to be associated with running performance. In marathon finishers, the longest mileage covered per training session was the best predictor for the successful completion of a marathon (Yeung, Yeung, & Wong, 2001). Scrimgeour, Noakes, Adams, and Myburgh (1986) found that runners training for more than 100 km per week had significantly faster race times over 10 to 90 km than athletes covering less than 100 km. Bale, Bradbury, and Colley (1986) reported, on 60 male runners, that elite runners with higher training frequency, higher weekly training volume, and longer running experience performed better in a 10-km run. According to Hewson and Hopkins (1996), seasonal weekly durations of moderate continuous running were correlated for runners specialising in longer distances. Billat, Demarle, Slawinski, Paiva, and Koralsztein (2001) reported that top class marathon runners trained for more total kilometers per week, and at a higher velocity, than runners at a lower level, and Scott and Houmard (1994) described peak running velocity as highly related to 5-km run times. When the training of runners up to the marathon distance was analysed, volume of training seemed important since several parameters, such as workout days, total workouts, total kilometers, mean kilometers per workout, longest mileage covered per training session, total training minutes, maximal kilometers of running per week, mean kilometers per week, and mean kilometers per day, seemed related to a marathon performance (Hagan, Smith, & Gettman, 1981; Hagan, Upton, Duncan, & Gettman, 1987; Yeung, *et al.,* 2001).

A 100-km run is the first step in gaining experience for runners wishing to compete in ultra-running over longer distances of several hundreds to thousands of kilometers. The aim of this study was to determine predictor variables for race time, and to create an equation for predicting a 100-km race time, using anthropometric and training variables, in order to help athletes preparing for a 100-km ultra-marathon. Regarding the present literature, it was hypothesized, firstly, that body mass, Body Mass Index, and circumference of the upper arm would be related to race time in successful finishers of a 100-km ultra-run. Secondly, it was hypothesized that training volume would also be associated with race time.

Method

Participants

To increase the sample size, data were collected in four subsequent years of a 100-km ultra-run. The organiser of the 100-km run in Biel, Switzerland, contacted all participants in the race, in the years 2007 to 2010, via a separate newsletter at the time of inscription into the race, and asked if they would participate in the study. About 1,500 male Euro-American runners started in the race each year; a total of 180 male ultra-runners volunteered to participate in the study over this four-year period. 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 ages and anthropometric variables of these athletes are summarised in Table 1 and their training variables in Table 2.

TABLE 1

Bivariate Association of Age and Anthropometric Variables With Race Time for the 169 Ultra-runners

Variable	*M*	*SD*	*r*	*p*
Age, yr.	46.5	10.2	.24	.0018
Body mass, kg	74.1	93.4	.20	.0097
Body height, m	1.77	0.06	.04	ns
Body Mass Index, kg/m^2	23.4	2.2	.29	.0002
Circumference of upper arm, cm	29.2	3.0	.26	.0006
Circumference of thigh, cm	54.2	3.2	.14	ns
Circumference of calf, cm	38.4	2.36	−.01	ns
Length of leg, cm	87.1	4.3	.04	ns
Percent body fat, %	16.1	4.3	.45	<.0001

Note.—Results are presented as means and standard deviations. The value of *p* is shown in case of significant association.

TABLE 2

Bivariate Association of Training Variables and Prerace Experience With Race Time For the 169 Ultra-runners

Variable	*M*	*SD*	*r*	*p*
Mean weekly hours in running	7.6	6.3	−.21	.005
Mean weekly kilometers in running	70.3	27.6	−.43	<.0001
Mean speed in running during training, km/hr.	10.7	1.5	−.56	<.0001
Number of finished marathons ($n = 160$)	31	47	−.11	ns
Personal best time in a marathon, min.	205.5	30.0	.65	<.0001
Number of finished 100-km runs ($n = 115$)	7	9	.24	.01
Personal best time in a 100-km run, min.	673.0	124.5	.72	<.0001

Note.—Results are presented as means and standard deviations. The value of *p* is shown in case of a significant association.

Race

The 100-km run in Biel, Berne, Switzerland, generally takes place during the night of the first weekend in June, starting at 10:00 p.m. The race course is mainly asphalt, with some trail running, and the athletes have to climb a total altitude of 645 meters on a loop of 100 km. The organiser of the event prepared a total of 17 aid stations offering an abundant variety of food and beverages. The athletes were also allowed the support of a cyclist who could supply additional food and clothing, if necessary. In all 4 yr., the general weather conditions were comparable, the temperature at the start being 15 to 18° C, night lows of 8 to 10° C, and daily highs of 25 to 28° C the following day. There was no rain or wind.

Measures

Immediately before the start of the race, body mass, body height, and the skin-fold thicknesses at eight sites were measured in order to calculate Body Mass Index and percent body fat using the anthropometric method. Body mass was measured using a commercial scale (Beurer BF 15, Beurer GmbH, Ulm, Germany) to the nearest 0.1 kg. Body height was measured using a stadiometer to the nearest 1 cm. Skin-fold data were obtained using a skin-fold calliper (GPM-Hautfaltenmessgerät, Siber & Hegner, Zurich, Switzerland) and recorded to the nearest 0.2 mm. One trained investigator took all the skin-fold measurements as intertester variability is a major source of error in skin-fold measurements (Kispert & Merrifield, 1987). The skin-fold measurements were taken once for the eight skin-folds, then the procedure was repeated twice more by the same investigator; the mean of the three measurements was then subjected to the analysis. According to Becque, Katch, and Moffatt (1986), readings were performed 4 sec. after applying the calliper to ensure the reliability of skin-fold measurements. An intratester reliability check was conducted on 27 male and 11 female runners prior to testing. Intra-class correlation (ICC) within the two judges was excellent for both men and women for all anatomical measurement sites ($ICC > 0.9$; Knechtle, Joleska, Wirth, Knechtle, Rosemann, & Senn, 2010). Circumferences and length of limbs were measured using a nonelastic tape measure (cm; KaWe CE, Kirchner and Welhelm, Germany). Length of the right leg was measured from *trochanter major* to *malleolus lateralis* to the nearest 0.1 cm, again on the right side. 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; circumference of the right thigh was taken at the level where the skin-fold thickness of the 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. The percentage of body fat was calculated using the following anthropometric formula from Ball, Altena, and Swan

(2004): percent body fat = 0.465 + 0.180(Σ7SF) − 0.0002406(Σ7SF)^2 + 0.0661(age), where Σ7SF = sum of skin-fold thickness of pectoralis, axilla, triceps, subscapular, abdomen, suprailiac, and thigh.

Upon inscription to the study, the participants were instructed to keep a comprehensive training diary until the start of the race. All training units in running were recorded, showing the distance in kilometers and the duration. In addition, every athlete indicated his number of finished marathons on a flat course, together with his personal best time, including the year this was achieved. The number of finished 100-km runs and the personal best time achieved were also reported.

Statistical Analysis

Data are presented as means and standard deviations. In order to reduce the variables for the stepwise linear regression analysis, bivariate correlation analysis between age and anthropometric (see Table 1) and training variables (see Table 2) was performed using Pearson correlation analysis. These variables have previously been investigated in literature on endurance athletes. Stepwise multiple-regression analysis was then used to determine the best variables correlated to race performance. A power calculation was performed according to Gatsonis and Sampson (1989). To achieve a power of 80% (two-sided Type I error of 5%) to detect a minimal association between race time and anthropometric variables of 20% (i.e., coefficient of determination $r^2 = .2$), a sample of 40 participants was required. An alpha level of 0.05 was used to indicate significance. A probability value of less than 0.05 was accepted as significant.

Results

Among these 180 ultra-runners, 169 athletes completed the 100 km within 713 ($SD = 131$) min., running at an average speed of 8.7 ($SD = 1.5$) km/h. Eleven (6.5%) did not finish within the time limit of 21 hr. The anthropometric characteristics are summarised in Table 1. In the bivariate analysis, age, body mass, Body Mass Index, circumference of upper arm, and percent body fat were related to race time. The training variables are summarised in Table 2. Mean weekly running hours, mean weekly running kilometers, mean speed in training, personal best time in a marathon, the number of finished 100-km ultra-runs, and the personal best time in a 100-km ultra-run were associated with race time. Stepwise multiple regression showed that when age and anthropometric and training variables were considered (Model 1), training speed ($p < .0001$), mean weekly running kilometers ($p < .0001$), and age ($p < .0001$) had the best correlation to the 100-km race time. Performance may be predicted ($n = 169$, $r^2 = .43$) by the following equation: 100-km race time (min.) = 1,085.60 − 36.26 × (training speed, km/hr.) − 1.43 × (training volume, km/wk.) + 2.50 × (age,

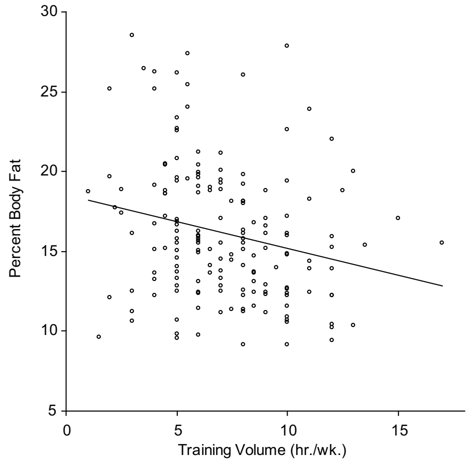

FIG. 1. Percent body fat was negatively and significantly related to the average weekly hours in running ($r = -.25$, $p = .0013$).

yr.). When age was not considered, but only anthropometric and training variables (Model 2), stepwise multiple regression showed that training speed ($p < .0001$), training volume per week ($p < .0001$), and body fat ($p < .015$) had the best correlation with the 100-km race time. Performance may be predicted ($n = 169$, $r^2 = .42$) by the following equation: 100-km race time (min.) = 1,107.41 − 37.21 × (training speed, km/h) − 1.13 × (train-

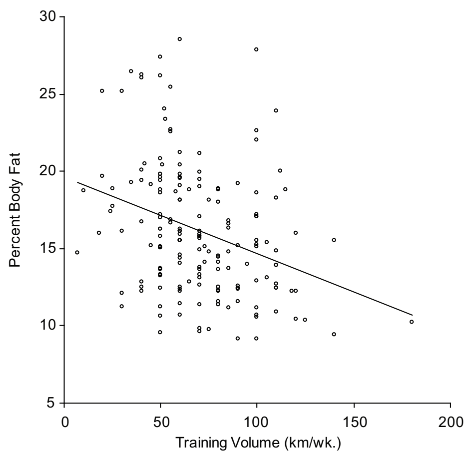

FIG. 2. Percent body fat was negatively and significantly related to the average weekly kilometers in running ($r = -.33$, $p < .0001$).

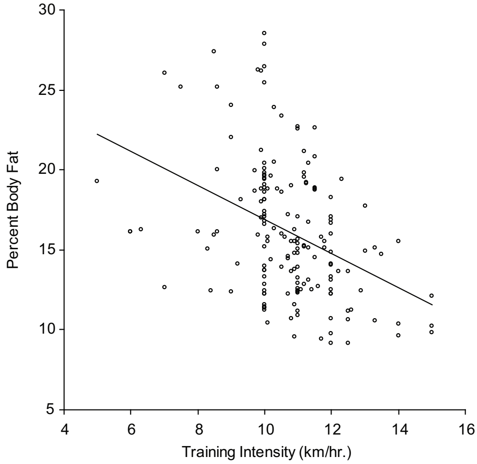

FIG. 3. Percent body fat was negatively and significantly related to the average running speed during training ($r = -.40$, $p < .0001$).

ing volume, km/wk.) + 5.16 × (body fat, %). When age, anthropometric and training variables, and personal best marathon time were included (Model 3), stepwise multiple regression showed that training speed ($p < .0001$), personal best marathon time ($p < .0001$), and age ($p < .0001$) had the best correlation with the 100-km race performance. Performance may be predicted ($n = 169$, $r^2 = .43$) by the following equation: 100-km race time

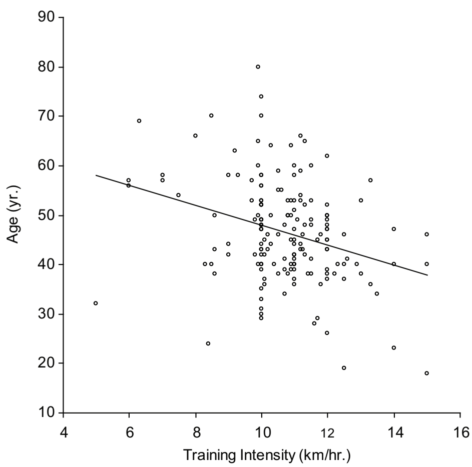

FIG. 4. Age was negatively and significantly related to the average running speed during training ($r = -.28$, $p = .0002$).

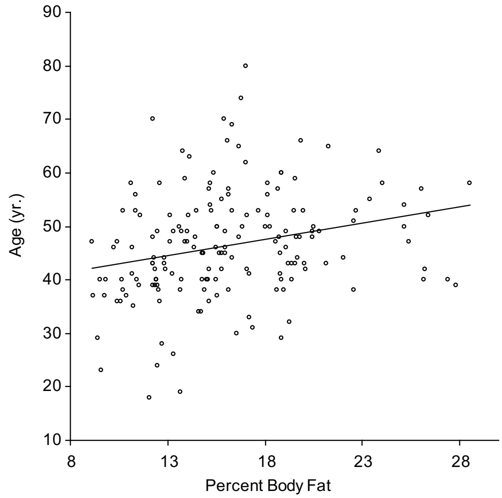

FIG. 5. Age of the runners was significantly and positively related to percent body fat ($r = .31$, $p < .0002$).

(min.) = 428.82 – 24.33 × (training speed, km/h) + 1.77 × (personal best marathon time, min.) + 3.81 × (age, yr.). When age, anthropometric and training variables, and personal best 100-km race time were considered (Model 4), stepwise multiple regression showed that a personal best 100-km race time ($p < .0001$) and age ($p < .0001$) had the best correlation with the 100-km race time. Performance may be predicted ($n = 114$, $r^2 = .57$) by the

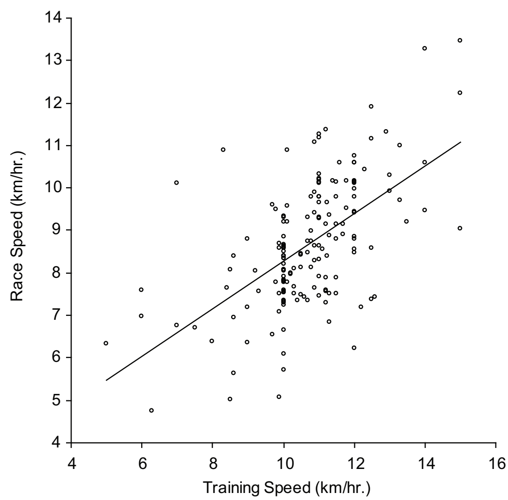

FIG. 6. Speed in training correlated highly significantly and positively with speed during the race ($r = .58$, $p < .0001$; $n = 169$).

following equation: 100-km race time (min.) = −44.0 – 0.81 × (personal best 100-km race time, min.) + 4.68 × (age, yr.). Percent body fat was significantly and negatively related to weekly running hours (see Fig. 1), weekly running kilometers (see Fig. 2), and speed in running during training (see Fig. 3). Age was significantly and negatively related to speed in run training (see Fig. 4), but not to volume in training. Also, age was significantly and positively related to percent body fat (see Fig. 5). Speed in training correlated highly significantly to speed in the race (Fig. 6).

Discussion

The aim of this study was to determine predictor variables for a 100-km race time and then create an equation, using anthropometric and training variables, to help athletes preparing for a 100-km ultra-marathon. Regarding the present literature, it was hypothesized that both anthropometric variables (such as body mass, Body Mass Index, circumference of upper arm) and training variables (such as training volume) would be associated with race time. Respecting the existing literature on anthropometric and training variables relating to endurance performances, apart from age, the variables of body mass, body height, Body Mass Index, circumferences of limbs, length of leg, volume and intensity of training, and personal best times were included in the bi- and multivariate analyses. Although anthropometric variables such as body mass, Body Mass Index, circumference of upper arm, and percent body fat were related to 100-km race times in the bivariate analysis, only age and training variables were significant in the multivariate analysis.

Anthropometry in the Bivariate Analysis

Regarding the association between the anthropometric variables and race time, the ‘classic’ anthropometric characteristics, for distances up to the marathon and ultra-endurance distances, such as body mass (Bale, *et al.*, 1986; Knechtle, *et al.*, 2009), percent body fat (Hagan, *et al.*, 1987; Hoffman, *et al.*, 2010), and circumference of upper arm (Knechtle, *et al.*, 2009; Knechtle, *et al.*, 2008) and Body Mass Index (Hagan, *et al.*, 1987; Lucia, Esteve-Lanao, Oliván, Gómez-Gallego, San Juan, Santiago, *et al.*, 2006; Hoffman, 2008) were related to 100-km race times in these male ultra-marathoners. Body height (Bale, *et al.*, 1986; Maldonado, Mujika, & Padilla, 2002; Loftin, Sothern, Koss, Tuuri, Vanvrancken, Kontos, *et al.*, 2007), however, was not related.

Training in the Bivariate Analysis

In the bivariate analysis, mean weekly running hours, mean weekly running kilometers, mean speed in training, personal best time in a marathon, the number of finished 100-km ultra-runs, and personal best time in a 100-km ultra-run were associated with 100-km race times. There are several studies of runners, up to the marathon distance, showing that increased volume and intensity of training are of importance for running performance. Top-class marathoners train for more total kilometers per week and at a higher velocity, compared to high-level runners (Billat, *et al.,* 2001). Christensen and Ruhling (1983) concluded that improved performance in marathon runners was associated with higher aerobic capacity and years of training, rather than with body dimensions. Scrimgeour, *et al.* (1986) showed that runners training for more than 100 km per week had significantly faster run times in running events between 10 km to 90 km, compared to runners with less training.

Predictor Variables For a 100-km Race Time

When the significant variables of the bivariate analysis were entered into the stepwise multiple linear regression analysis, in all four models the anthropometric variables were no longer related to the 100-km race time, except when age was excluded in Model 2. When we inserted age and anthropometric and training variables, without the personal best times, the variables of age and intensity and volume of training predicted race time, but anthropometric variables did not. When the personal best time in a marathon was inserted, apart from age and intensity of training, the personal best marathon time was a predictor variable for race time. In recent studies, an association of the personal best marathon time with race performance has been described. In ultra-runners during a 24-hr. run, the personal best marathon time was significantly and positively correlated to the achieved distance during the run (Knechtle, *et al.,* 2009). 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 nonfinishers (Knechtle, *et al.,* 2009). In a multi-stage mountain ultra-marathon, personal best time in marathon running was associated with total race time (Knechtle, Knechtle, & Rosemann, 2010). However, in these studies, the anthropometric variables showed no association with ultra-endurance performances, in contrast to this actual investigation. Intensity in training seemed, nonetheless, to be important for ultra-runners. This finding confirms Billat, *et al.* (2001), who demonstrated that, apart from training volume, the intensity is also of importance for marathon runners. Several other authors, however, concluded that volume in training is predominantly associated with improved running performance (Bale, *et al.*, 1986; Scrimgeour, *et al.*, 1986; Yeung, *et al.,* 2001).

Association Between Body Fat and Training

Body fat percentage and skin-fold thicknesses were related to average weekly running hours (see Fig. 1), average weekly running kilometers (see Fig. 2), and average running speed during training (see Fig. 3).

A problem in the correlation analysis is the fact that significant correlation does not prove cause and effect. The athletes with low body fat may be able to run fast during training but, also, intense training can lead to a reduction in skin-fold thicknesses (Legaz & Eston, 2005). In two studies of multi-stage ultra-runs over 338 km (Knechtle, *et al.*, 2009) and 1,200 km (Knechtle, *et al.*, 2008), a significant association of the upper arm circumference and the total run time was described. In this present investigation, in a run over 100 km, the upper arm circumference was not related to performance. Presumably, it is only in distances of more than 100 km that this anthropometric parameter shows a significant association with running performance times.

Implications of the Study and Future Research Directions

Athletes and coaches in ultra-endurance running should be aware that mainly training variables were associated with race time in a 100-km ultra-run. This is also reflected in the highly significant association between speed in training during running and speed during the race. Anthropometric attributes seem to be of less importance regarding the prediction of a 100-km race time. In future studies, the aspect of motivation to train harder and faster for such a race should be further investigated.

Conclusions

Although anthropometric variables were related to race time in a 100-km ultra-marathon in the bivariate analysis, age and both training variables, such as intensity and weekly running volume, and prerace experience, such as personal best marathon time, predict race time in a 100-km ultra-marathon. The aspect of motivation to train intensively for such an ultra-endurance run should be investigated in future studies. This might be the key to a successful finish in a multi-stage ultra-endurance run across a country or a continent.

REFERENCES

Anderson, T. (1996) Biomechanics and running economy. *Sports Medicine,* 22, 76-89.

Bale, P., Bradbury, D., & Colley, E. (1986) Anthropometric and training variables related to 10-km running performance. *British Journal of Sports Medicine,* 20, 170-173.

Ball, S. D., Altena, T. S., & Swan, P. D. (2004) Comparison of anthropometry to DXA: a new prediction equation for men. *European Journal of Clinical Nutrition,* 58, 1525-1531.

Becque, M. D., Katch, V. L., & Moffatt, R. J. (1986) Time course of skin-plus-fat compression in males and females. *Human Biology,* 58, 33-42.

Billat, V. L., Demarle, A., Slawinski, J., Paiva, M., & Koralsztein, J. P. (2001) Physical and training characteristics of top-class marathon runners. *Medicine & Science in Sports & Exercise,* 33, 2089-2097.

Christensen, C. L., & Ruhling, R. O. (1983) Physical characteristics of novice and experienced women marathon runners. *British Journal of Sports Medicine,* 17, 166-171.

Gatsonis, C., & Sampson, A. R. (1989) Multiple correlation: exact power and sample size calculations. *Psychological Bulletin*, 106, 516-524.

Hagan, R. D., Smith, M. G., & Gettman, L. R. (1981) Marathon performance in relation to maximal aerobic power and training indices. *Medicine & Science in Sports & Exercise*, 13, 185-189.

Hagan, R. D., Upton, S. J., Duncan, J. J., & Gettman, L. R. (1987) Marathon performance in relation to maximal aerobic power and training indices in female distance runners. *British Journal of Sports Medicine*, 21, 3-7.

Hewson, D. J., & Hopkins, W. G. (1996) Specificity of training and its relation to the performance of distance runners. *International Journal of Sports Medicine*, 17, 199-204.

Hoffman, M. D. (2008) Anthropometric characteristics of ultramarathoners. *International Journal of Sports Medicine*, 29, 808-811.

Hoffman, M. D., Lebus, D. K., Ganong, A. C., Casazza, G. A., & Van Loan, M. (2010) Body composition of 161-km ultramarathoners. *International Journal of Sports Medicine*, 31, 106-109.

Kispert, C. P., & Merrifield, H. H. (1987) Interrater reliability of skinfold fat measurements. *Physical Therapy*, 67, 917-920.

Knechtle, B., Duff, B., Schulze, I., Rosemann, T., & Senn, O. (2009) Anthropometry and pre-race experience of finishers and nonfinishers in a multistage ultra-endurance run—Deutschlandlauf 2007. *Perceptual and Motor Skills*, 109, 105-118.

Knechtle, B., Duff, B., Welzel, U., & Kohler, G. (2009) Body mass and circumference of upper arm are associated with race performance in ultra-endurance runners in a multi-stage race—the Isarrun 2006. *Research Quarterly for Exercise and Sport*, 80, 262-268.

Knechtle, B., Joleska, I., Wirth, A., Knechtle, P., Rosemann, T., & Senn, O. (2010) Intra- and inter-judge reliabilities in measuring the skin-fold thicknesses of ultra runners under field conditions. *Perceptual and Motor Skills*, 111, 105-106.

Knechtle, B., Knechtle, P., & Rosemann, T. (2010) Race performance in male mountain ultra-marathoners: anthropometry or training? *Perceptual and Motor Skills*, 110, 721-735.

Knechtle, B., Knechtle, P., Schulze, I., & Kohler, G. (2008) Upper arm circumference is associated with race performance in ultra-endurance runners. *British Journal of Sports Medicine*, 42, 295-299.

Knechtle, B., Wirth, A., Knechtle, P., & Rosemann, T. (2010) Training volume and personal best time in marathon, not anthropometric parameters, are associated with performance in male 100-km ultrarunners. *Journal of Strength and Conditioning Research*, 24, 604-609.

Knechtle, B., Wirth, A., Knechtle, P., Zimmermann, K., & Kohler, G. (2009) Personal best marathon performance is associated with performance in a 24-h run and not anthropometry or training. *British Journal of Sports Medicine*, 43, 836-839.

Legaz, A., & Eston, R. (2005) Changes in performance, skinfold thicknesses, and fat patterning after three years of intense athletic conditioning in high level runners. *British Journal of Sports Medicine*, 39, 851-856.

Loftin, M., Sothern, M., Koss, C., Tuuri, G., Vanvrancken, C., Kontos, A., & Bonis, M. (2007) Energy expenditure and influence of physiologic factors during marathon running. *Journal of Strength and Conditioning Research*, 21, 1188-1191.

Lucia, A., Esteve-Lanao, J., Oliván, J., Gómez-Gallego, F., San Juan, A. F., Santiago, C., Pérez, M., Chamorro-Viña, C., & Foster, C. (2006) Physiological characteristics of the best Eritrean runners: exceptional running economy. *Applied Physiology, Nutrition, and Metabolism*, 31, 530-540.

Maldonado, S., Mujika, I., & Padilla, S. (2002) Influence of body mass and height on the energy cost of running in highly trained middle- and long-distance runners. *International Journal of Sports Medicine*, 23, 268-272.

Marti, B., Abelin, T., & Minder, C. E. (1988) Relationship of training and life-style to 16-km running time of 4000 joggers: the '84 Berne "Grand-Prix" Study. *International Journal of Sports Medicine*, 9, 85-91.

Morgan, D. W., Martin, P. E., & Krahenbuhl, G. S. (1989) Factors affecting running economy. *Sports Medicine*, 7, 310-330.

Nettleton, S., & Hardey, M. (2006) Running away with health: the urban marathon and the construction of "charitable bodies." *Health (London)*, 10, 441-460.

Pate, R. R., Macera, C. A., Bailey, S. P., Bartoli, W. P., & Powell, K. E. (1992) Physiological, anthropometric, and training correlates of running economy. *Medicine & Science in Sports & Exercise*, 24, 1128-1133.

Saunders, P. U., Pyne, D. B., Telford, R. D., & Hawley, J. A. (2004) Factors affecting running economy in trained distance runners. *Sports Medicine*, 34, 465-485.

Scott, B. K., & Houmard, J. A. (1994) Peak running velocity is highly related to distance running performance. *International Journal of Sports Medicine*, 15, 504-507.

Scrimgeour, A. G., Noakes, T. D., Adams, B., & Myburgh, K. (1986) The influence of weekly training distance on fractional utilization of maximum aerobic capacity in marathon and ultra marathon runners. *European Journal of Applied Physiology*, 55, 202-209.

Yeung, S. S., Yeung, E. W., & Wong, T. W. (2001) Marathon finishers and non-finishers characteristics: a preamble to success. *Journal of Sports Medicine and Physical Fitness*, 41, 170-176.

Accepted September 27, 2010.