ANTHROPOMETRIC AND PHYSIOLOGICAL DETERMINANTS OF RUNNING PERFORMANCE IN MIDDLE- AND LONG-DISTANCE RUNNERS

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Abstract:

The aim of the present study was to compare anthropometric, body composition and physiological parameters in middle- and long-distance runners of the same performance level and to identify variables that could predict the probability of being either a middle- or a long-distance runner. National-level middle-distance (n=20, body mass M=70.5, SD=6.3 kg, body height M=1.80, SD=0.04 m,) and long-distance (n=20, body mass M=69.0, SD=4.5 kg, body height M=1.81, SD=0.05 m) runners performed an incremental test on a treadmill. Anthropometric and body composition parameters were measured and different body length and mass ratios were calculated. Middle- and long-distance runners did not differ (p>.05) in their leg mass, length proportions, in their measured anthropometric or body composition parameters, except for the lower leg length. Performance in middle-distance runners was best described by the lower leg to upper leg mass ratio (Adj R^2=.41; p<.05) and the second ventilatory threshold time (Adj R^2=.33; p<.05), while the performance in long-distance runners was best described by the total time on a treadmill (Adj R^2=.36; p<.05). The constructed model showed that VO_{2max}time (OR=1.01, 95% CI 1.001-1.012) and age (OR=1.57; 95% CI 1.065-2.310) classified middle- and long-distance runners in their specialties. In conclusion, the results of the present study demonstrate the relevance of specific anthropometric parameters in predicting middle- but not long-distance running performance.

Key words: *runners' specialty, dual energy x-ray absorptiometry, running performance, leg mass, leg length*

Introduction

Running performance is related to a variety of physiological characteristics in national (Maldonado, Mujika, & Padilla, 2002) and elite (Rabadan, et al., 2011) level middle- and long-distance runners. In addition to high maximal oxygen consumption (VO_{2max}), endurance performance in different running distances is also related to maximal running speed (v_{max}) and oxygen cost of running (Cr) (Rabadan, et al., 2011). It has been found that national (Maldonado, et al., 2002) and elite (Rabadan, et al., 2011; Svedenhag & Sjödin, 1984) level long-distance runners present significantly higher VO_{2max} values than the middle-distance runners. Elite long-distance runners (Rabadan, et al., 2011) demonstrate higher second ventilatory threshold (VT_2) values compared to middle-distance runners (Beaver, Wasserman, & Whipp, 1986). VO_{2max} values in elite male runners increase in running distances up to 3,000 m, showing a greater importance of this parameter for performance prediction, while VO_{2max} appears to be similar from 3,000 m to marathon distances, thus indicating similar importance of VO_{2max} for these running events (Legaz, et al., 2007). Furthermore, middle- and long-distance runners use different training volumes and intensities which lead to different adaptations in aerobic performance parameters (Rabadan, et al., 2011).

In addition to different physiological parameters, several anthropometric and body composition values are known to be associated with running performance in elite Caucasian middle- and long-distance (Arrese & Ostariz, 2006) and ultramarathon (B. Knechtle, P. Knechtle, Schulze, & Kohler, 2008) runners. For example, body height and mass (Maldonado, et al., 2002), fat and fat-free mass (Winter & Hamley, 1976), arm circumference

(B. Knechtle, et al., 2008), different lower limb skinfolds and circumferences (Arrese & Ostariz, 2006; Legaz & Eston, 2005; Tanaka & Matsuura, 1982) and also sum of three (Kong & de Heer, 2008) and six (Legaz & Eston, 2005) skinfolds have been related to distance running performance. Runners with a proportionally smaller amount of body mass concentrated in the extremities, particularly in the legs, would perform less work moving their body segments during running if all other factors are unchanged (Myers & Steudel, 1985). Therefore, leg mass and the distribution of leg mass might be important characteristics of distance runners' performance (Myers & Steudel, 1985). Despite a number of studies describing different anthropometric parameters related to running performance over different distances (B. Knechtle, et al., 2008; Kong & de Heer, 2008; Arrese & Ostariz, 2006; Legaz & Eston, 2005; Maldonado, et al., 2002; Tanaka & Matsuura, 1982), there is paucity of studies investigating the associations between specific anthropometric ratios of lower limb and running performances in different running events. However, there is a study (Lucia, et al., 2008) that has described leg length ratio to body height in top-level Spanish distance runners in comparison with one of the best Eritrean runners.

The aim of the current study was to compare anthropometric, body composition and physiological parameters in middle- and long-distance runners of the same performance level. The second aim was to identify variables that predict the probability of being either a middle- or a long-distance runner. It was hypothesized that if the performance level of runners is the same according to the International Association of Athletics Federations (IAAF) scoring points, long-distance runners in comparison with middle-distance runners have: (i) lower body mass and lower body fat percent; (ii) smaller upper and lower leg circumferences; and (iii) higher speed at VT_2 and VO_{2max} intensities. Therefore, the identification of specific anthropometric and body composition proportions that could characterize middle- and long-distance runners would be important and could be used for talent identification and performance prediction.

Methods

Experimental approach to the problem

The IAAF scoring table was used to determine the performance level of athletes and to divide them into either a middle- or a long-distance runners group depending on which discipline score was higher. An incremental test on a treadmill was utilized to measure the basic physiological parameters. Since middle-distance race time is shorter and trainings are more intense but of lower volume compared with the long-distance race time and trainings (Rabadan, et al., 2011), we assumed that body composition and anthropometric parameters would be markedly different in these two groups of runners.

Subjects

A total of 40 male national-level middle- and long-distance runners participated in the study. Athletes were recruited from different training groups across the country and were contacted through e-mail. The runners were classified as middle-distance runners (n=20) when competing from 800 to 1,500 m and long-distance runners (n=20) when competing from 3,000 m to marathon distances based on the highest International Association of Athletics Federations (IAAF) scores during the last season in the corresponding distance (Table 1). The 3,000 m distance was used as the cut-off value because it has been shown that VO_{2max} values increase from 100 to 3,000 m and plateau for the longer distances (3,000 m to marathon) (Legaz, et al., 2007). The participation criteria were a minimum of five times per week regular training sessions during the last three years, average monthly mileage during the last year of at least 240 km and inclusion in the top 20 at the National Athletics Association ranking list at least in one distance between 800 m and marathon. The best performance of athletes involved in several events was established using the Scoring Tables of the IAAF (Legaz & Eston, 2005). Study procedures and protocols were approved by the local ethics committee. All the procedures and possible risks were described and the participants were familiarized with the procedures before providing a written informed consent to participate in the experiment.

Table 1. Characteristics of the middle-distance (MD) and long-distance (LD) runners (mean±s)

	MD (n=20)	LD (n=20)	Cohen d
Age (year)	21.1±3.4	25.4±3.8**	1.19
Height (m)	1.80±0.04	1.81±0.05	0.22
Body mass (kg)	70.5±6.3	69.0±4.5	0.27
BMI ($kg \cdot m^{-2}$)	21.6±1.5	21.1±1.2	0.37
Body fat (%)	8.1±2.0	7.6±1.9	0.26
IAAF (points)	829±99	814±85	0.16
VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$)	64.2±5.8	67.4±5.9	0.55
vVO_2max ($km \cdot h^{-1}$)[a]	17.8±1.3	19.0±1.0**	1.03
vVT_2 ($km \cdot h^{-1}$)[b]	16.4±1.3	17.3±0.8*	0.83

Note. *p<.05; **p<.01 significant differences between middle-distance and long-distance runners. [a] Treadmill speed at the maximal oxygen uptake intensity. [b] Treadmill speed at the second ventilatory threshold.

Procedures

At the end of the outdoor season, the participants performed an incremental running test on a treadmill (HP Cosmos Quasar, Nussdorf-Traunstein, Germany) until voluntary exhaustion. At least 24 hours prior to testing, the athletes were encouraged to abstain from any hard training and competition. All the runners were fully familiarized with the use of this apparatus. The initial treadmill speed was set at 8 $km \cdot h^{-1}$ and was increased by 2 $km \cdot h^{-1}$ after every three minutes up to 14 $km \cdot h^{-1}$. From that point onwards the speed was increased by 1 $km \cdot h^{-1}$ every three minutes until voluntary exhaustion (Zafeiridis, Sarivasiliou, Dipla, & Vrabas, 2010). The treadmill inclination was set at a constant gradient of 1% to simulate outdoor running (Lucia, et al., 2006; Jones & Doust, 1996). Expired gases were measured continuously by the oxygen analyzer Metamax 3B (Cortex Biophysic GMBH, Leipzig, Germany). Metabolic cart was calibrated before each measurement according to the manufacturer's instructions.

VO_{2max} was defined as the highest average VO_2 during a 30 second period and a failure to increase VO_2 further despite an increase in work rate (Wasserman, Hansen, Sue, Stringer, & Whipp, 2005). Speed at VO_{2max} (vVO_{2max}) was defined as the highest treadmill speed at the end of the test. If the runner could not complete the three-minute period of the last speed, the vVO_{2max} was calculated using the last completed velocity (*vlast*) and the relative duration of the last uncompleted velocity (*frac*) as follows: $vVO_{2max} = vlast + frac$ (Kaikkonen, Hynynen, Mann, Rusko, & Nummela, 2010). The second ventilatory threshold (VT_2) was determined as the second rise in the ventilation and VT_2 speed (vVT2) was defined as a corresponding treadmill speed (Rabadan, et al., 2011).

Body height (Martin metal anthropometer) and body mass (A&D Instruments Ltd, Oxfordshire, UK) of the participants were measured to the nearest 0.1 cm and 0.05 kg, respectively. In total, six skinfolds (*triceps, subscapular, iliac crest, abdominal, front thigh* and *medial calf*), 13 girths (*head, neck, arm relaxed, arm flexed* and *tensed, forearm, wrist, chest, waist, gluteal, thigh, mid-thigh, calf, ankle*), and eight lengths (*acromiale-radiale*, *radiale-stylion, midstylion-dactylion, iliospinale height, trochanterion height, trochanteriontibiale laterale, tibiale-laterale height, tibiale mediale-sphyrion tibiale*) were recorded. The sum of six skinfolds (*triceps, subscapular, iliac crest, abdominal, front thigh* and *medial calf*) was calculated (Lucia, et al., 2006; Legaz & Eston, 2005). The series of anthropometric measurements were taken by a trained anthropometrist who had previously shown test-retest reliability of r>.9. The Centurion kit instrumentation was used (Rosscraft, Surrey, BC, Canada) for skinfold, girth and length measurements. All anthropometric variables were measured according to the protocol recommended by the International Society for Advancement of Kinanthropometry (ISAK) (Norton & Olds, 1996). The following calculations were made:

upper leg length = iliospinale–tibiale laterale and *total leg length = upper leg length + tibiale mediale-sphyrion tibiale (lower leg length*).

In addition, the following anthropometric ratios were calculated:

1. *leg mass to body mass: leg mass (kg)/body mass (kg)*100*
2. *upper leg (thigh) mass to body mass: upper leg (kg)/body mass (kg)*100*
3. *lower leg (calf) mass to body mass: calf mass (kg)/body mass (kg)*100*
4. *lower leg (calf) mass to upper leg (thigh) mass: calf mass (kg)/thigh mass (kg)*100*
5. *leg length to body height: leg length (m)/total body height (m)*100*
6. *upper leg (thigh) length to body height: upper leg (m)/total body height (m)*100*
7. *lower leg (calf) length to body height: lower leg (m)/total body height (m)*100*
8. *lower leg (calf) length to upper leg (thigh) length: lower leg (m)/upper leg (m)*100*

Relative subcutaneous fat patterning was assessed by the distribution of skinfolds on the body: *extremity (triceps, front thigh, medial calf)/trunk (subscapular, iliac crest, abdominal) skinfolds ratio (ET ratio)* (Legaz & Eston, 2005).

Body composition was measured by Dual Energy X-ray Absorptiometry (DXA) (DPX-IQ Lunar Corporation, Madison, WI, USA) with the participant in supine position (Hetland, Haarbo, & Christiansen, 1998). Total fat and lean mass were measured for total body, upper leg (thigh) and lower leg (calf).

Statistical analyses

Middle- and long-distance groups were compared with Student *t*-test or Mann-Whitney U-test. Cohen's d (Cohen, 1988) was calculated to indicate effect size and practical meaningfulness. The effect sizes were judged using Lipsey's criteria and considered medium when d was between 0.45 and 0.89, and large when d was higher than 0.90 (Lipsey, 1990). Pearson's or Spearman's correlation coefficients were used to determine the correlation between IAAF points and anthropometric and body composition characteristics. The variables that showed statistically significant correlation with the IAAF points were used in linear regression. Binary logistic regression was applied to determine which variables had most influence on the odds of being either a middle-distance or a long-distance runner. Goodness-of-fit tests included model chi-squares to determine model appropriateness and

Wald statistics to evaluate the contributions of predictor variables. Finally, using the same variables derived from the binary logistic regressions, discriminant analyses were performed to control a function that would predict the specialty to which an athlete might be best suited. All calculations were performed using SPSS v.17 software for Windows (SPSS, Chicago, IL, USA). The level of significance was set at $p<.05$. Statistical power for significant differences was higher than .82.

Results

Long-distance runners showed significantly higher VT_2 and VO_{2max} speeds than middle-distance runners when running on a treadmill (Table 1). The long-distance runners were significantly older than the middle-distance runners. However, the two groups of runners did not differ significantly as for their body mass. Running performance (IAAF points) of long-distance runners was significantly related to the total running time on a treadmill (tTotal) (r=.63). Of the physiological parameters only VT_2 time was significantly related (r=.57) to performance in middle-distance runners.

Middle- and long-distance runners did not differ significantly in values for the measured skinfolds, circumferences and lengths (Table 2). The only exception was lower leg length which was significantly longer in the middle-distance runners. The studied groups did not differ significantly in total body, upper and lower leg fat mass and fat-free mass.

Correlation analysis showed that the running performance (IAAF points) in middle-distance runners was significantly related to lower leg mass to upper leg mass ratio (r=.67) and total body lean mass (r=.61) from the anthropometric and body composition parameters. All other relationships between the running performance and the measured variables were not significant in middle-distance runners. In contrast, there were no parameters from the measured and calculated anthropometric and body composition variables that were significantly related to running performance in long-distance runners.

From the calculated length proportions, only lower leg to body length ratio (Table 3) differentiated significantly between the middle- and long-distance runners. However, there were no differences in body mass proportions between the middle- and long-distance runners. In the long-distance group, upper leg to body length ratio was correlated with performance (r=0.59).

Linear regression analyses indicated that the anthropometric variables (Adj R^2=.41) predicted running performance better than the physiological variables (Adj R^2=.33) in middle-distance runners (Table 4). Therefore, lower leg mass to upper leg mass ratio appeared to be the best predictor of running performance in middle-distance runners. However, the total time on a treadmill characterized 36% of the variance in running performance in long-distance runners, while there were no anthropometric parameters or indices to predict the running performance in long-distance runners (Table 4). Subsequently binary logistic regression was used to find out which indices were important to categorize athletes as either middle- or long-distance runners. The constructed model showed that VO_{2max}time (OR=1.01, 95% CI

Table 2. Anthropometric and body composition parameters in the middle-distance (MD) and long-distance (LD) runners (mean ± s)

	MD (n=20)	LD (n=20)	Cohen's
Skinfolds (mm)			
Triceps	5.4±1.9	4.3±1.4	0.66
Subscapular	6.6±0.9	6.0±1.3	0.54
Iliac crest	7.0±2.2	6.3±1.0	0.41
Abdominal	7.6±2.4	6.1±1.7	0.72
Front thigh	6.3±1.8	6.9±2.2	0.30
Medial calf	4.1±2.2	4.0±2.5	0.04
Sum of 6 skinfolds	35.5±8.3	33.4±7.6	0.26
Circumferences (cm)			
Arm (relaxed)	27.6±1.8	26.5±1.8	0.61
Waist	75.1±3.2	74.3±3.0	0.26
Upper leg (thigh)	53.1±2.7	51.8±1.4	0.60
Mid-thigh	50.9±2.9	49.5±1.6	0.60
Lower leg (calf)	37.3±1.7	36.4±1.2	0.54
Ankle	24.6±3.4	22.8±0.9	0.72
Lengths (cm)			
Total leg length	92.7±4.1	89.3±5.7	0.68
Upper leg (thigh) length	52.5±2.9	51.3±3.6	0.37
Lower leg (calf) length	39.9±2.1	38.0±2.5*	0.82
Body composition			
Total body fat mass (kg)	5.8±1.6	5.3±1.3	0.34
Lean body mass (kg)	61.9±5.3	60.2±6.1	0.30
Upper leg fat mass (kg)	1.5±0.5	1.2±0.5	0.60
Upper leg fat (%)	13.1±4.4	10.8±3.8	0.56
Upper leg lean tissue (kg)	9.4±1.1	9.5±0.8	0.10
Upper leg total mass (kg)	11.3±1.2	11.2±1.0	0.09
Lower leg fat mass (kg)	0.3±0.2	0.3±0.1	0.00
Lower leg fat (%)	6.6±3.0	5.7±2.2	0.34
Lower leg lean tissue (kg)	3.7±0.3	3.7±0.3	0.00
Lower leg total mass (kg)	4.4±0.4	4.2±0.3	0.57
Total leg total mass (kg)	15.7±1.4	15.4±1.2	0.23

Note. *p<.05 significant differences between the middle-distance and long-distance runners

Table 3. Proportions of body masses and lengths in the middle-distance (MD) and long-distance (LD) runners (mean ± s)

	MD (n=20)	LD (n=20)	Cohen's
Proportions of body masses			
Leg/body mass (%)	22.3±0.5	22.4±0.9	0.14
Upper leg/body mass (%)	16.0±0.5	16.1±0.9	0.14
Lower leg/body mass (%)	6.2±0.5	6.1±0.3	0.24
Lower leg/upper leg mass (%)	39.0±3.6	38.1±2.7	0.28
Proportions of body lengths			
Leg/body length (%)	51.1±1.7	49.7±2.3	0.69
Upper leg/body length (%)	8.9±1.3	28.6±1.6	0.21
Lower leg/body length (%)	22.0±0.9	21.2±1.0*	0.84
Lower leg/upper leg length (%)	76.7±3.9	74.3±3.6	0.64
E/T ratio[a]	0.77±0.21	0.82±0.24	0.22

Note. *p<.05 significant differences between the middle-distance and long-distance runners. [a] Extremity (triceps, front thigh, medial calf)/trunk (subscapular, iliac crest, abdominal) skinfold ratio.

Table 4. Results of linear regressions to predict the middle- and long-distance performance (IAAF points)

MIDDLE-DISTANCE					
Model 1	B	SE	β	*t*	p
Lower leg/upper leg mass (%)	-18.69	5.38	-.67	-3.48	.00
Constant	1547.62	210.47		7.35	.00
R^2	.45				
Adj R^2	.41				
SE	77.71				
$F(df_n,df_d)$	12.08				
Model 2	B	SE	β	*t*	p
VT_2time (sec)[a]	0.20	0.08	.57	2.60	.02
Constant	631.41	79.90		7.90	.00
R^2	.57				
Adj R^2	.33				
SE	73.57				
$F(df_n,df_d)$	6.73				
LONG-DISTANCE					
Model 1	B	SE	β	*t*	p
tTotal (sec)[b]	0.41	0.13	.63	3.27	.005
Constant	162.30	202.54		0.80	.435
R^2	.40				
Adj R^2	.36				
SE	66.20				
$F(df_n,df_d)$	10.69				

Note. [a] Second ventilatory threshold time. [b] Total time on treadmill.

1.001-1.012) and age (OR=1.57; 95% CI 1.065-2.310) classified athletes according to their specialties. The subsequent discriminant analyses confirmed that these variables were sufficient to produce a function that would predict the specialty of athletes (Wilks' l=.613; c^2=15.17; p=.00).

Discussion and conclusions

This study was done to determine and compare the specific anthropometric and body composition parameters together with the selected physiological values that were hypothesized to predict the probability of being either a middle- or a long-distance runner.

In this study there were no significant differences between the middle- and long-distance runners in the overall performance level (IAAF points) and the VO_{2max} values. The athletes showed VO_{2max} values (middle-distance runners: M=64.2, SD=5.8 ml·kg^{-1}·min^{-1}; long-distance runners: M=67.4, SD=5.9 ml·kg^{-1}·min^{-1}) similar to those in earlier studies in well-trained Caucasian and African runners (Esteve-Lanao, Foster, Seiler, & Lucia, 2007; Legaz, et al., 2007; Weston, Mbambo, & Myburgh, 2000). Previous studies have shown differences between VO_{2max} values of middle- and long-distance runners in elite Caucasian athletes (Rabadan, et al., 2011; Legaz, et al., 2007; Maldonado, et al., 2002) with VO_{2max} higher in long-distance than in middle-distance runners. The average VO_{2max} of the same performance level elite runners from 3,000 m to marathon was not different, thus indicating similar importance of VO_{2max} for these running events (Legaz, et al., 2007). However, distances from 100 to 3,000 m indicated different contributions of VO_{2max} to running performance (Legaz, et al., 2007). The athletes in the present study were not world elite runners and therefore their specialization for middle- and long-distance running was not so definite. It can be suggested that VO_{2max} values do not differ significantly in national-level middle- and long-distance runners with the same body height, body mass, body fat percentage and performance level.

In our study, the speed corresponding to VO_{2max} and VT_2 (vVO_{2max}, vVT_2) was significantly lower in middle-distance than in long-distance runners. This is in line with an earlier study that indicated significantly lower vVO_{2max} in middle-distance runners compared to long-distance runners (Rabadan, et al., 2011). On the one hand, the difference in vVO_{2max} can be due to our testing protocol, which consisted of three minutes running stages and thus was more suitable for long-distance runners. On the other hand, long-distance runners train at higher training volumes and therefore they have better aerobic performance compared with middle-distance runners. Competitions for middle-distance runners last up to around four minutes, while the performance time in long-distance runners starts at around eight and a half minutes. The long-distance runners in the current study reached their VT_2 and VO_{2max} at M=19:30, SD=1:53 (min:sec) and M=24:25, SD=2:59 (min:sec), respectively; while the middle-distance runners did the same at M=16:46, SD=4:05 (min:sec) and M=21:00, SD=3:45 (min:sec), respectively. An earlier study has shown that running speed at the anaerobic threshold was closely related to the running speed over 5,000 m distance and above but no such relationship was found for shorter distances (Maffulli, Capasso, & Lancia, 1991).

To the best of our knowledge, very few studies have calculated different leg masses and length proportions to find out which of these proportions characterize running performance better in middle- and long-distance runners, and whether the same performance level middle- and long-distance runners can be distinguished according to these proportions. From the calculated leg mass and length proportions only lower leg to body height ratio was different in middle- and long-distance groups (see Table 3). At the same time, lower leg to upper leg mass ratio correlated with the running performance in middle-distance (r=-.69) but not in the long-distance group. Previously, it has been hypothesized that runners with a proportionally smaller amount of body mass concentrated in the extremities, particularly in the legs, would perform less work moving their body segments during running, assuming that all other factors were similar (Myers & Steudel, 1985). Myers and Steudel (1985) showed that adding a few grams of mass on the feet/ankle evokes an increase in the metabolic rate. Earlier, it has been explained that increased metabolic rate might be caused by the forward and backward movement of the limbs relative to the center of mass. Therefore, added load to the limbs would increase both – the total mass to be carried and mechanical energy expended in raising and accelerating the center of mass and in oscillations in kinetic energy of the limbs relative to the center of mass. In addition, it has been shown that a given mass added to subject's limbs causes 1.5 up to 5.5 times higher energy expenditure than if the same amount of mass were added to the subject's center of mass (Myers & Steudel, 1985). Therefore, leg mass and the distribution of mass in legs might be important characteristics in the performance of runners (Kong & de Heer 2008; Larsen, 2003). The present study showed that lighter lower leg in relation to upper leg was related to performance in middle-distance runners but no such relationship was found in long-distance runners. These discrepancies between the middle- and long-distance runners remain unclear. Reducing body mass and leg mass in particular is ought to enhance running performance as a consequence of reducing the kinetic energy required to accelerate and decelerate the limbs (Fudge, et al., 2006). An average increment in O_2 by 0.7–1% per 100 g weight added to the footwear has been found earlier (Jones, Knapik, Daniels, & Toner, 1986).

Accordingly, our results demonstrate that the performance variation in the long-distance running group was best described by the total time on a treadmill. Surprisingly, neither the anthropometric nor body composition parameters accounted for significant variance in the long-distance running performance. Lower leg mass to upper leg mass ratio described 41% of the variance in the performance in middle-distance runners, while the VT_2 time described only 33% of their running performance. Accordingly, it can be concluded that the proportion of lower leg mass describes the performance of middle-distance runners better than the physiological parameters. One explanation could be that the middle-distance performance has a higher anaerobic energy contribution than the long-distance performance. However, this remains unclear at present.

The constructed model showed that the odds of belonging to the long-distance group were higher if an athlete was older and the VO_{2max} time increased. One additional year increases the odds of belonging to the long-distance group by 57% when the athletes have the same VO_{2max} values. The athletes of the same age have 1% greater odds of belonging to long-distance group when VO_{2max} time increases by one second. At the beginning of their running career the athletes start with middle-distance events and later move to the long-distance events. However, elite-level middle-distance athletes do not tend to go from middle-distance to long-distance events, but it can be the case in national-level athletes.

It is important to note that the limitation of this study was the performance level of the investigated athletes, therefore the results of the study are applicable to national level runners only. Low performance level of the athletes participating in this study can also be the reason why there was a lack of significant anthropometric differences between the studied groups. On the other hand, it is one of a few studies in which both the middle- and long-distance runners are at the same performance level (IAAF points), thus allowing for their physiological and anthropometric parameters to be compared.

In summary, the results of the present study indicate the importance of specific anthropometric parameters for the prediction of the middle-distance but not the long-distance running performance in well-trained national-level athletes with relatively high VO_{2max} values. According to the results it can be suggested that national-level middle- and long-distance runners of even performance level and with no significant differences in anthropometric and/or body composition characteristics also present similar values for VO_{2max}. In addition, age and VO_{2max} time are important parameters to classify athletes as either middle- or long-distance runners.

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ANTROPOMETRIJSKE I FIZIOLOŠKE ODREDNICE USPJEŠNOSTI TRČANJA U TRKAČA NA SREDNJE I DUGE PRUGE

Cilj je ovoga rada bio usporediti antropometrijske i fiziološke parametre te sastav tijela trkača na srednje i duge pruge koji su slične kvalitetne razine te identificirati varijable koje bi mogle prognozirati vjerojatnost njihova pripadanja skupini srednjoprugaša ili dugoprugaša. Trkači nacionalnog ranga koji trče na srednje (n=20, tjelesna masa M=70,5 kg, SD=6,3 kg, tjelesna visina M=1,80 m, SD=0,04 m) i duge pruge (n=20, tjelesna masa M=69,0 kg, SD=4,5 kg, tjelesna visina M=1,81 m, SD=0,05 m) podvrgnuti su progresivnom testu opterećenja. Izmjerene su antropometrijske karakteristike i sastav tijela te su izračunati omjeri longitudinalnih dimenzija različitih dijelova tijela i njihove mase. Srednjoprugaši i dugoprugaši se nisu razlikovali (p>0,05) u masi nogu, proporcijama duljina te izmjerenim antropometrijskim parametrima ili varijablama sastava tijela. Izvedba trčanja na srednje pruge najbolje je definirana pomoću varijable omjer mase potkoljenice i mase natkoljenice (Adj R^2=0,41; p<0,05) te vremena postizanja drugog ventilacijskog praga (Adj R^2=0,33; p<0,05), dok je uspješnost trčanja u dugoprugaša bila najbolje definirana pomoću varijable ukupno vrijeme trčanja na progresivnom testu opterećenja (Adj R^2=0,36; p<0,05). Konstruirani model je pokazao da su vrijeme postizanja VO_{2max} na progresivnom testu opterećenja (OR=1,01, 95% CI 1.001-1.012) i dob trkača (OR=1,57; 95% CI 1.065-2.310) najviše pridonijeli klasifikaciji trkača u njihove discipline. Zaključno, rezultati ovog istraživanja ukazali su na važnost specifičnih antropometrijskih karakteristika u predviđanju uspješnosti u trčanju na srednje pruge, ali ne i u trčanju na duge pruge.

Ključne riječi: *trkačka specijalnost, DEXA, uspješnost trčanja, masa noge, duljina noge*