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Morphological Differences of Elite Croatian Track-and-Field Athletes

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A B S T R A C T

In this sudy we present the morphological characteristics of 54 Croatian national level track-and-field athletes. 21 anthropometric body measures were taken on a sample of 15 sprinters (S), 16 endurance sprinters (S4), 10 middle-distance runners (MD) and 13 long-distance runners (LD). Body fat percentage, body mass index and somatotype were also calculated. Canonical discriminative analysis showed significant difference between the athletes of various running events, in the measures of body volume and body fat, while no significant difference was found in the variables of longitudinal and transversal dimensions of the skeleton. ANOVA and Student t-test for independent samples showed statistically significantly higher thigh and lower leg circumference in sprinters, as well as greater upper arm skinfold in middle-distance runners. The mesomorphic component is a dominant characteristic of somatotype of the runners in all events, whereas the ectomorphic component is the least marked.

Key words: *runners, track and field, anthropometrics, body composition, somatotype*

Introduction

The measurement and apprehension of basic morphological characteristics of an athlete is the foundation on which a training process may be built. Specific anthropometric characteristics are needed to be successful in certain sporting events, although, expert opinions often differ when it comes to this matter. Body composition analysis is also a standard procedure, that helps to improve and optimise the athlete's training process, as well as to imply on possible health problems.

There are number of papers dealing with anthropometrics and body type of athletes in various sports[1–4], as well as different playing positions in a specific sport[5,6]. Rare, but very interesting are studies on the influence of morphological characteristics on top sport achievements, as the research carried out on javelin throwers[7]. Running events in track-and-field are marked by an exceptional variety of duration of a single event, energetic demands and the tempo of energy release. Considering the fact that runners need to carry their weight, which means they need to overcome the force of gravity on different distances, unlike, for example, rowers or swimmers, this stipulates a specific (lean) body composition as a prerequisite for more efficient and economic performance in a single event.

Although previous research has demonstrated that athletes in all running events have less body fat compared to most other disciplines[6,8–15], according to our knowledge, no sistematic research regarding the morphological characteristics of the athletes in various running events, has been conducted so far. For previous studies it can be concluded that sprinters have a large span of body height (from 1.57 to 1.90 m) and body mass (from 63 to 90 kg)[2]. Especially in sprinters the presence of long lower extremities is found to be advantage in achieving the top results. In middle distance runners it appears that moderate height and light weight accompanied with low body fat is the predominant morphologic profile. The variations in body height are present with the variations in the length of the event, higher athletes are found in shorter events and they also have a tendency to greater mesomorphy[3]. Best marathon runners are usually short and have low body mass (1.70 m and 61 kg[4] on average, respectively). The low body mass is a consequence of very low body fat percentages (usually lower than 7%, sometimes even under the recommended limits).

The aim of this study is to analyze morphological characteristics and differences between top national track-and-field athletes, in regard to specific events (sprinters,

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endurance sprinters, middle-distance and long-distance runners).

Materials and Methods

The sample consisted of 54 runners, divided in four groups: 15 sprinters (100 and 200m, S), 16 endurance sprinters (400m, S4), 10 middle-distance runners (MD) and 13 long-distance runners (LD). The average age of all runners was 21.9 ± 5.4 yrs (S=21.1 ± 4.8; S4=20.3 ± 4.7; MD=18.6 ± 2.4 and LD=27.2 ± 4.7). All subjects are in the top 15 on the Croatian Athletic Association rank-list for the specific event. The runners were fully informed of all experimental procedures before giving their written informed consent to participate. The study was approved by the ethics committee of Faculty of Kinesiology.

All measurements were conducted at the Sports Diagnostic centre at the Faculty of Kinesiology, University of Zagreb, according to the standards and instructions of the International Biological Program[16]. 21 morphological body measures were taken: body height and body mass, leg length, arm length, arm span, shoulder width, elbow diameter, knee diameter, circumferences of upper arm (extende and flexed), forearm, thigh, lower leg, chest and abdomen, skinfolds of the back, upper arm, chest, abdomen, thigh, lower leg and suprailiocristal. Body composition (percentage of lean body mass and body fat), body mass index and somatotype components (according to Heath-Carter, 1984) were calculated from anthropometric measures.

Body composition of the athletes was assesed by the skinfold method[4], and the equation for the assessment of body density (BD). The value of body density was inserted into the equation for the estimation of body fat (% of body fat = (495/BD – 450); Siri, 1956). New methods for assessment of body composition have been developed, but it appears that the skinfold method is still the standard, when it comes to practical field and/or even laboratory testing. The method of Heath and Carter (1984), which is based on the Sheldon's somatotype classification, was applied to determine the somatotype characteristics.

The statistical package Statistica for Windows 7.0 was used for the statistical analysis. Basic statistical descrip-

TABLE 1
ANTHROPOMETRIC AND MORPHOLOGICAL CHARACTERISTICS OF ALL SUBJECTS

	X	*SD*	*Min*	*Max*
Body height (cm)	181.76	5.21	171.10	195.20
Body mass (kg)	72.58	6.74	56.00	85.90
Arm span (cm)	183.15	7.27	164.70	198.10
Leg length (cm)	102.87	3.28	96.40	112.20
Arm length (cm)	79.10	3.03	72.00	85.00
Shoulder width (cm)	40.83	1.71	37.40	44.40
Knee diameter (cm)	9.67	0.48	8.50	10.60
Elbow diameter (cm)	6.94	0.30	6.30	7.70
Circ. of the upper arm ext. (cm)	28.41	2.41	23.00	33.30
Circ. of the upper arm flex. (cm)	31.15	2.72	24.80	37.00
Circ. of the forearm (cm)	26.38	1.43	23.40	29.70
Circ. of the upper leg(cm)	55.94	3.02	49.50	62.40
Circ. of the lower leg (cm)	37.26	1.96	33.30	42.00
Circ. of the abdomen (cm)	78.39	3.78	71.30	87.00
Skinfold of the back (mm)	8.44	1.90	5.00	14.20
Skinfold of the upper arm(mm)	6.84	2.17	3.60	13.27
Skinfold of the thigh (mm)	8.40	3.48	4.00	18.20
Skinfold of the shank (mm)	5.45	2.04	2.93	14.20
Skinfold of the chest (mm)	4.64	1.31	2.50	8.73
Skinfold suprailiocristal (mm)	8.30	3.86	3.50	22.50
Skinfold of the abdomen (mm)	6.76	3.48	3.80	25.60
body fat (%)	5.86	2.21	2.38	12.66
BMI	21.95	1.60	18.65	25.39
Sum of 7 skinfolds (mm)	48.84	14.50	29.83	95.93
S_I – endomorph comp.	2.10	0.71	1.00	5.00
S_II – mesomorph comp.	3.77	0.98	1.50	6.00
S_III – ectomorph comp.	3.36	0.83	2.00	5.50

tive parameters have been calculated – mean (X), standard deviation (SD) and range (R), for all subjects and for each group (S, S4, MD, LD) separately. Kolmogorov – Smirnov test was used to test if data are normally distributed. The differences between the groups were analysed with the canonical discriminative analysis. The differences between all groups of runners in the manifested space have been analysed by ANOVA, whereas paired t-tests for independent variables were used to test the differences between particular variables between groups. Statistical significancy was set at $p<0.05$.

Results

The obtained results are presented in Tables 1–3. All variables were normally distributed ($p>0.22$).

Basic descriptive parameters and the results of ANOVA for morphological characteristics of the subjects are shown in Tables 1 and 2.

The latent differences between the groups of runners, analysed by the use of canonical discriminative analysis, are shown in Table 3.

Discussion

The wide age span, from 17 to 36 years of age, confirms the fact that runners can maintain their sports career for very long, which is especially noticeable in sprint and long-distance events (especially half-marathon and marathon, Table 1). In this sample, which comprised athletes of different running events who were, or still are a part of the junior or senior national team, the youngest athletes were middle-distance runners and the oldest, as expected, were long-distance runners.

The average body height of all subjects (Table 1), as well as for particular groups (Table 2), is almost identical to the average height of the male population in Croatia[18] which implies that this measure cannot be used in the selection process for specific running events. Redford (1990)

TABLE 2
ANTHROPOMETRIC AND MORPHOLOGICAL CHARACTERISTICS OF SUBJECTS ACCORDING TO THE RUNNING DISCIPLINES

	S (n=15)	*S4 (n=16)*	*MD (n=10)*	*LD (n=13)*	
Body height (cm)	182.7 ± 5.3	181.3 ± 4.7	180.13 ± 5.4	181.9 ± 5.2	
Body mass (kg)	76.0 ± 4.6	72.7 ± 6.8	68.7 ± 6.3	71.5 ± 7.8	*, #
Arm span (cm)	184.0 ± 5.4	183.4 ± 8.3	179.4 ± 6.7	184.6 ± 8.1	
Leg length (cm)	103.3 ± 3.6	102.5 ± 3.6	102.0 ± 2.5	103.3 ± 3.3	
Arm length (cm)	79.4 ± 2.5	79.3 ± 3.2	77.3 ± 3.3	80.2 ± 2.8	
Shoulder width (cm)	41.1 ± 1.6	40.7 ± 1.7	40.4 ± 0.3	41.0 ± 1.8	
Knee diameter (cm)	9.9 ± 0.3	9.6 ± 0.5	9.6 ± 0.5	9.5 ± 0.6	
Elbow diameter (cm)	7.0 ± 0.3	6.9 ± 0.3	6.9 ± 0.3	6.8 ± 0.4	
Circ. of the upper arm ext. (cm)	29.3 ± 1.9	28.8 ± 1.7	27.3 ± 2.3	27.7 ± 3.3	
Circ. of the upper arm flex. (cm)	32.3 ± 2.3	32.0 ± 1.9	29.6 ± 1.8	30.0 ± 3.7	*, #
Circ. of the forearm (cm)	26.6 ± 1.1	27.0 ± 0.9	25.4 ± 1.3	26.1 ± 2.0	*, %
Circ. of the upper leg(cm)	57.9 ± 2.6	55.8 ± 2.7	54.9 ± 3.1	54.6 ± 2.9	**, &,#
Circ. of the lower leg (cm)	38.6 ± 2.0	37.0 ± 1.4	35.8 ± 1.8	37.2 ± 1.8	**, #
Circ. of the abdomen (cm)	79.1 ± 3.4	78.7 ± 4.4	78.1 ± 3.6	77.4 ± 3.8	
Skinfold of the back (mm)	8.6 ± 1.8	8.6 ± 2.1	8.9 ± 2.3	7.8 ± 1.5	
Skinfold of the upper arm(mm)	6.3 ± 1.9	6.4 ± 2.4	8.6 ± 2.4	6.7 ± 1.3	*,#,$
Skinfold of the thigh (mm)	8.0 ± 3.6	7.8 ± 4.2	10.4 ± 2.9	8.1 ± 2.5	
Skinfold of the shank (mm)	5.8 ± 2.7	5.5 ± 2.1	5.9 ± 1.9	4.7 ± 1.0	
Skinfold of the chest (mm)	4.6 ± 1.3	4.4 ± 1.3	5.1 ± 1.6	4.6 ± 1.2	
Skinfold suprailiocristal (mm)	6.0 ± 1.8	6.8 ± 2.4	9.3 ± 6.7	5.7 ± 1.2	
Skinfold of the abdomen (mm)	8.5 ± 3.7	7.9 ± 3.9	9.7 ± 4.9	7.5 ± 3.3	
Body fat percentage (%)	5.6 ± 2.1	5.3 ± 2.4	6.9 ± 2.7	6.0 ± 1.6	
Body mass index	22.8 ± 1.6	22.0 ± 1.4	21.2 ± 1.7	21.5 ± 1.4	*, #
Sum of 7 skinfolds (mm)	47.7 ± 14.6	47.2 ± 16.0	57.8 ± 16.7	45.3 ± 8.2	
S_I – endomorph comp.	2.0 ± 0.5	2.1 ± 0.7	2.6 ± 1.1	1.9 ± 0.4	
S_II– mesomorph comp.	4.2 ± 1.1	3.8 ± 0.7	3.5 ± 1.2	3.4 ± 0.9	
S_III – ectomorph comp.	3.0 ± 1.0	3.3 ± 0.7	3.7 ± 0.9	3.6 ± 0.6	

**p<0,01;* p<0,05; # p<0,05 for S and MD; $; p<0,05 for S4 and MD; & p<0,05 for S and LD; % p<0,05 for S4 and LD found a large span in height in runners, that ranged from 1.57 m to more than 1.90 m, and concluded that runners, especially sprinters, come in »a remarkable range of shapes and sizes«[2].

The values of body fat percentage and the sum of all skinfolds indicate that runners, regardless the event, have prominantly less body fat compared to other athletes of most sport disciplines[9,11,12]. The only statistically significant difference between groups in this study is for the upper arm skinfold, which was higher in middle-distance runners compared to others. The lowest body mass index (the relation between mass and square height) was found in distance runners, and the highest in sprinters. Considering similar body fat percentage in all groups, higher BMI indicates higher lean body mass, which is confirmed by the values of the mesomorph component, as well as by the values of the circumferences of the limbs (Table 2). Sprinters had the highest values in all body volume measures, 400 meter runners had slightly lower values, whereas middle and long-distance runners had lowest, and about equal values. Sprinters have significantly higher circumferences of the upper and lower leg, and upper arm (in flexed position), compared to middle and long distance groups of runners (Table 2). The same trend is observed for other body volume parameters. Usually, sprinters are the heaviest of all the runners, but not the tallest. Long legs are advantageous in sprinters, but only to an optimal level which is in correlation to their height. If the legs are above this optimal length this could cause problems in producing the rapid leg cadence that is a prerequisite for good sprinting[19].

The somatotype of Croatian runners is similar between groups. They all have a moderate ectomorph constitution, which means a moderate muscularity and elongated shape, as the dominant features of the constitution. The endomorphic component is the least developed, as expected. The somatotype of Croatian runners is comparable to the somatotype of the 1984 Olympics participants[20]: sprinters 1.7 – 5.2 – 2.8, 400 meter runners 1.5 – 4.6 – 3.4, middle-distance runners 1.5 – 4.3 – 3.6, long-distance runners 1.4 – 4.2 – 3.7 (numbers presented in order as in the Heath-Carter method[1]: endomorphic – mesomorphic – ectomorphic component). The endomorphic component is somewhat more marked in our runners, while the mesomorphic, and even more the ectomorphic component are less marked. One might question the influence of the annual phase in the training cycle on the variation of anthropometric and morphologic features. There are no reports in the literature on the stability of morphological parameters throughout the season. This study was performed at the beginning of the annual training cycle, so we could assume a somewhat higher body fat percentage and endomorphic component, than it would be expected during the competitive phase. Probably this also explains why long distance runners in our sample have the highest values of body fat percentage, while usually they have very low fat content. For example, Pollock and his coworkers (1977) found body fat values of only 4.7% (determined by hydrostatic weighing) in male marathon runners.

The hypothetical existence of morphological distinctions between the athletes of various running events has been confirmed (Canonical R_1=0.79; $p<0.05$). The centroid of the sprinters group has been settled on one pole (C_S = 1.58), and the centroid of the long-distance runners and middle-distance runners has been settled on the other pole of the first (the only statistically significant) discriminative function (C_{LD} = –1.30 i C_{MD} = –1.45). The centroid of the 400 meter runners took position in the middle of the discriminative function (C_{S4} = 0.49). No single measure contributed to the factorial structure of the discriminative function, most probably because of the high correlation of anthropometric variables.

The results of a separate canonical discriminative analysis based only on the variables for body volume, body mass and body composition measures are presented in Table 3. The first statistically significant discriminative function clearly explained the difference between the groups of athletes of various running events. The position of the sprinters group centroid on the positive pole (C_S = 1.21), and the positions of the middle-distance and long-distance runners centroids on the negative pole of the discriminative function (C_{MD} = –0.82 and C_{LD} = –0.76) confirmed previous statements that short-distance runners are more muscular (Table 2). Namely, the factorial structure of the first discriminative function emphasizes the influence of the volume and body mass variables, especially the musculature of the lower extremities (circumference of the thigh and lower leg). The musculature of the lower extremities generates strong, powerful movements starting from the reaction and pushing out of

TABLE 3
CANONICAL DISCRIMINATIVE ANALYSIS FOR THE VARIABLES OF BODY VOLUME, BODY MASS, AND BODY FAT OF THE RUNNERS

	DF 1	*DF 2*	*DF 3*
Circ. of the upper arm ext.	0.39	–0.18	0.10
Circ. of the upper arm flex.	0.48	–0.35	0.11
Circ. of the forearm	0.31	–0.46	0.43
Circ. of the upper leg	0.57	0.06	–0.12
Circ. of the lower leg	0.57	0.16	0.60
Body mass	0.45	–0.01	0.32
Body fat percentage	–0.17	0.24	–0.31
	DF 1	DF 2	DF 3
LD	–0.76	0.42	0.54
MD	–0.82	0.38	–0.70
S	1.21	0.40	–0.02
S4	–0.00	–0.96	0.01
Rc	0.65	0.54	0.38
p-level	0.000	0.020	0.181

Discriminant functions (DF), canonical correlation (Rc), error size (p) the starting block, through the acceleration, and, less, maintainance of the maximal velocity throughout running distance.

The centroid position on the discriminative function, voluminosity (body mass and circumferences of different body segments), of the group of long-distance runners is determined primarily by lower circumferences of the thigh and lower leg. Namely, the weekly training volume of the long-distance runners often reaches 180 km or more. Considering the fact that such training regime is characterised by moderate intensity, higher muscle mass gives no advantage, and, as well as excessive body fat, would make an unnecessary extra load.

The centroid position of the 400 m runners group placed in the middle (C_{S4} = 0.00) between the sprinters and middle-distance runners is logical and expected, regarding the energy demands of such events, as well as the volume and characteristics of the training process. Top performers in 400 m, 800 m and 1500 m events demand highly developed aerobic and anaerobic systems[10,22], although the share of particular energy sources varies in differing proportion from event to event – the shorter the track, the more dominant is the anaerobic energy supply, and *vice versa*, in long-distance events it is mostly aerobic. So, through the anthropometric dimensions they have a tendency towards greater mesomorphy, moderate height, light weight and low body fat.

Conclusion

Average values of the basic anthropometric measures (body mass and height) of Croatian nationally top-ranked runners in various running events are similar to those of the general population. In comparison to the general population, as well as to other sports disciplines, track-and-field athletes have lower body fat percentage, and statistically significantly higher values for circumferences of all body segments.

A mesomorphic component is dominant in runners of all events, the ectomorphic component is less dominant, whereas the endomorphic component is the least marked.

The canonical discriminative analysis showed that runners of various running events significantly differ in morphological measures, especially in dimensions of body volume and body fat. On the manifest level, only thigh and lower leg circumference statistically differ, being significantly higher in sprinters, as well as the upper arm skinfold, which is significantly higher in middle-distance runners.

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MORFOLOŠKE RAZLIKE ATLETIČARA HRVATSKOG NACIONALNOG RANGA RAZLIČITIH TRKAČKIH DISCIPLINA

S A Ž E T A K

Morfološke osobitosti proučavane su na 46 atletičara Hrvatskog nacionalnog ranga. Kod 15 trkača na 100 i 200 m (S), 16 trkača na 400 m (S4), 10 trkača na srednje pruge (MD) te 13 trkača na duge pruge (LD) izmjerena je 21 morfološka mjera tijela, te su izračunati postotak masti, BMI i komponente somatotipa. Kanonička diskriminativna analiza ukazala je na postojanje razlike između atletičara različitih trkačkih disciplina u mjerama voluminoznosti i potkožnog masnog tkiva, dok nije izražena u varijablama longitudinalne i transverzalne dimenzioniranosti skeleta. ANOVA i Studentov t-test za nezavisne uzorke ukazali su na statistički značajnu razliku u mjerama opsega natkoljenice i potkoljenice, koje su značajno više u sprintera, dok je nabor nadlaktice značajno viši u trkača na srednje pruge. Mezomorfna komponenta konstitucije dominantna je karakteristika u trkača svih disciplina, dok je ektomorfna komponenta manje a endomorfna komponenta najslabije izražena.