ANTHROPOMETRIC CHARACTERISTICS AND PERFORMANCE OF 110m AND 400m MALE HURDLERS

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Abstract:

The men's hurdle runs (110-m hurdles and 400-m hurdles) belong to a group of complex athletics events. Performance in hurdle races depends on motor abilities, technique and anthropometric profiles.

The aim of this longitudinal study (1994-1999) was to find relationships between male hurdle performance and various anthropometric and body composition parameters on 60 Polish hurdlers and 60 students of the Academy of Physical Education in Katowice, divided in two samples: 110-hurdlers and 400-m hurdlers ($N_{1,2}$=30). A Polish hurdler is the athlete who is tall (184.3 cm), has long lower limbs (97.7 cm) and large muscle circumferences (specially thigh and calf) as well as a low level of fat percentage (mainly thigh, triceps and abdominal). Also significant correlations ($p < 0.001$) between hurdle performances and body mass, muscle mass, LBM (kg), stature and arm and thigh circumferences appeared, stronger in the group of 110 than 400-m hurdlers. None of three somatotype components influenced the results in hurdle races. Principal component factor analysis condensed anthropometric and body composition parameters into three (*stature, muscle* and *fat*) dimensions which accounted for 52.4% of common variance. The correlation of the muscle factor with the hurdle performance yielded 0.45 ($p < 0.01$).

The best combination of variables for the prediction of hurdle-run results consisted of: stature, thigh girth and thigh skinfolds ($R = 0.66$, $r^2 = 0.44$, $F = 14.53$, $p < 0.001$).

***Key words**: anthropometric characteristic, body composition, somatotype, 110-m and 400-m hurdles*

ANTHROPOMETRISCHE EIGENSCHAFTEN UND LEISTUNG BEI DEN 110-m- UND 400-m- HÜRDENLÄUFERN

Zusammenfassung:

Männerhürdenläufe (der 110-m-Hürdenlauf und der 400-m-Hürdenlauf) gehören zu den komplexen athletischen Disziplinen. Sportliche Leistung im Hürdenlauf hängt von motorischen Fähigkeiten, Technik und dem anthropometrischen Profil ab.

Das Ziel dieser longitudinaler Studie war, den Zusammenhang zwischen der sportlichen Leistung im Männerhürdenlauf und verschiedenen anthropometrischen und Körperbauparametern fest zu stellen, bei 60 polnischen Hürdenläufen und 60 Studenten der Akademie für Sportausbildung, Katowice.

Die Hürdenläufer wurden in zwei Gruppen von 30 Personen verteilt: die 110-m- Hürdenläufer und 400-m-Hürdenläufer. Die Untersuchungen wurden in einem 6-jährigen Zeitraum (1994-1999) durchgeführt.

Der polnische Hürdenläufer ist ein hoher Sportler (184,3 cm), mit langen unteren Gliedermaßen (97,7 cm), großen Umfängen (besonders am Ober- und Unterschenkel) und einem niedriegen Körperfettanteil (meistens am Oberschenkel, Trizeps und Abdomen). Die Ergebnisse zeigten die bedeutende Korrelation ($p < 0,001$) der Hürdenlaufresultaten mit der Körpermasse, Muskelmasse, mit der fettfreien Körpermasse (kg), Statur sowie mit dem Arm- und Oberschenkelumfang. Die Korrelationen waren enger in der 110-m-Gruppe als in der 400-m-Gruppe. Keine der Somatotypkomponenten beeinflusste die Hürdenlaufresultaten. Die Hauptkomponentenanalyse, die die anthropometrischen und Körperbauparameter auf drei Faktoren (Statur, Muskel und Fett) verteilte, erklärte 52,4% der gemeinsamen Varianz. Die Korrelation zwischen dem Hürdenlaufergebnis und dem Faktor „Muskel"ertrug 0,45 (p < 0,01).

Die beste Variablenkombination zur Voraussage des Hürdenlaufergebnisses umfasst: die Statur, den Oberschenkelumfang und die Oberschenkelhautfalten (R = 0,66, r^2 = 0,44, F = 14,53, p < 0,001).

Schlüsselwörter: *anthropometrische Eigenschaften, Körperbau, Somatotyp, 110-m- und 400-m-Hürdenläuf*

Introduction

Hurdle runs (both 110 and 400 meters) are one of the most difficult track-and-field events. Results in these events depend on the motor abilities (speed, strength and endurance), coordination abilities (technique) and anthropometric parameters (Kostial, 1978; Sparrey, 1997; Iskra, 1999).

In the history of the Olympic Games (OG) runners with different somatic parameters won medals. Amongst them there were both tall (F.S. – 201 cm, third in the OG in 1996) and short hurdlers (E.O. – 173 cm, third in the OG in 1968), also heavy (R.K. – 88 kg Olympic champion in 1988) and light (F.M. – 68 kg, world champion in 1999) ones (Mappa & Quercetani, 1999).

Despite a large number of anthropometric variables Tanner (1964) described hurdlers as runners who had long and powerful legs and strong arms.

The anthropometric model of hurdlers since the Olympic Games in Tokyo has presumably been altered. The main reasons behind this transformation were the introduction of synthetic tracks and changes in the training system towards pro-strength preparation (Alejo, 1993).

Till now, there have been no reports dealing solely with a hurdler's body composition and examining that problem in a complex manner (Sinning, 1996). The available studies relating to anthropometrics, somatotypes and the body components of hurdlers were part of larger investigations of different track-and-field events (Tanner, 1964; de Garay, Levine & Carter, 1972; Thorland, Johnson, Fagot et al., 1981; Fleck, 1983; Whithers, Craig, Bourdon & Norton, 1987; Rivera & Nevarez, 1993).

Hurdlers are most frequently combined with sprinters specializing in the 100m- up to 400m-events (Pipes, 1977; Krawczyk, Sklad & Majle, 1995). This approach is not appropriate because the specificity of the hurdle events differs fundamentally from sprint running. The hurdler has to clear 10 hurdles of 107cm height (110m) or 91 cm height (400 m). It is also incorrect to combine schematically the hurdlers specializing in the 110m event with the ones competing in the techniques of running and energy system (Ward-Smith, 1997). The knowledge of hurdlers somatic composition is essential in the selection process of young athletes (Tabacznik, Timoszenko & Chalilov, 1996; Sparrey, 1997).

In the group of high performance hurdlers anthropometric parameters (especially girths) and body composition (especially fat percentage) are helpful in monitoring the system of training (Blount, Hoskisson & Karchemny, 1990). The study of the Polish hurdlers was reasonable since in the years 1994-1999 they achieved high level performances.

The aims of this study were to describe the anthropometric characteristics of hurdlers and find the anthropometric, somatic and body composition differences between 110-m and 400-m hurdlers. An important practical aim was to find those parameters, which have the most essential influence on the results in hurdle races. Inspiration for this study was drawn from the study by Cleassens, Hlatky, Lefevre & Holdhaus (1994).

Hypothesis

1. There exist specific anthropometric and body composition parameters in the group of male hurdlers.
2. There are no marked differences between the somatotypes of hurdlers at different (110-m and 400-m) distances.
3. Most predictive somatic parameters in hurdle races are: stature, leg length and muscle mass.

Methods

60 Polish hurdlers were studied. They were divided into 30-person groups – 110-m (13.27 – 15.98 s) and 400-m (48.17 – 56.30 s) hurdle runners. Among the investigated hurdlers there were European-level hurdle athletes like the European Championship in 400-m hurdles (1998) and the Silver medallist of the World Junior Championships in 110-m hurdles (1997). The study of the Polish hurdlers was conducted over a period of 6 years (1994-1999); the measurements

were taken one day before competing in the Polish Athletics Championships (July – August). The control group consisted of students of the Academy of Physical Education in Katowice (n = 60). The anthropometric measurements were taken prior to the students' obligatory participation in the 110-m hurdles. The characteristics of each group are summarised in Table 1.

biiliocristal, biepicondylar humerus and femur, wrist). The measurements were conducted according to Martin's technique (1928), described by Drozdowski (1992).

The following girths were measured: chest, hip, abdominal, arm, forearm, thigh and calf, and the skinfolds: subscapular, triceps, abdominal, chest, front calf and suprailiac.

Table 1. Characteristics of the subjects (mean ± SD)

Group	Age (years)	Training age (years)	Results		
			Time (s)	Velocity (m/s)	Points[2)]
Hurdlers (n = 60)	21.0 ± 2.5	5.0 ± 2.3	-	-	1011.0 ± 103.1***
Students (n = 60)[1)]	21.3 ± 2.1	untrained	17.4 ± 0.3	6.3 ± 0.3	620.3 ± 105.8
110 m hurdlers (n = 30)	21.1 ± 3.1	5.4 ± 2.8	14.5 ± 0.8	7.6 ± 0.4	1014.0 ± 118.7
400 m hurdlers (n = 30)	20.9 ± 1.8	4.5 ± 1.6	52.9 ± 2.1	7.6 ± 0.3	1008.0 ± 86.7

[1)] – 110 hurdles run
[2)] – points according to tables in Spiriev and Kovacs (1987)
*** - difference between hurdlers and control – $p < 0.001$

In addition. the stature. body mass and body mass index (BMI) of the finalists of the Olympic Games and World Championships in the years 1991-1999 were calculated. The local Ethical Committee at the Silesian Medical Academy in Katowice approved the techniques and protocol of this project.

Sport level

Spiriev and Kovacs (1987) estimated the sport level of the hurdlers on the basis of the tables of performance scores. The tables provide scores (points) for every result in each track-and-field event. Using the performance scores made it possible to compare the results achieved by the hurdlers specializing in the two different events (110 m and 400 m) as well as enabling a combination of a group of "hurdlers" (n = 60).

Anthropometry

A wide range of anthropometric dimensions was used for measuring the subjects. The measurements included lengths (stature, leg length = basis - symphysion, trunk length = suprastemale – symphysion, arm length = acromiale-dactylion$_3$, thigh length = symphysion - tibiale, calf length = tibiale - sphyrion, foot length = pterion - acropodion) and breadths (transverse foot breadth, biacromial, transverse chest breadth, chest depth,

Body mass index (BMI) was calculated (kg x m^{-2}) from height and weight. Anthropometric measurements were taken by the same investigator from the Anthropology Department of the Academy of Physical Education in Katowice. The bilateral dimension was measured on the left side. The equipment used included Philips HP 5352 (body mass), Martin's anthropometer (length parameters), Siber-Hegner anthropometer (breadths), metal tape (girths) and Harpenden caliper (skinfolds).

Body composition

The body fat percentage was estimated according to the method of Piechaczek (1976). This method, estimating the athlete's relative body fat, has been commonly used in Poland for nearly 25 years. As it has been established in a number of investigations, there is a clear convergence of results obtained by means of the method of Piechaczek and bioelectrical impedance method (BIA) (Wit, Piechaczek, Blachno & Busko, 1998).

To predict relative body fat (%BF) the equation including 3 skinfolds (triceps. chest and calf) was used: %BF = -8.948988 + 0.044703 log (triceps) + 0.062820 log (chest) + 0.027324 log (calf). The absolute values of body fat and absolute and relative values of lean body mass (LBM) were determined from %BF.

Muscular mass

The muscular mass (MM) was determined by means of anthropometric measurements (thigh and calf skinfolds, forearm, thigh and calf circumferences). MM was estimated according to the Martin, Spenst, Drinkwater and Clarys equation (Martin et al., 1990).

Somatotype

The somatotypes were determined anthropometrically using the Heath and Carter formulae (Carter & Hearth, 1990).

Statistics

Data were processed with the statistical programme package "Statistica" 5.1. for Windows. All data are expressed as means ± standard deviations (SD). An unpaired Student's *t*-test was used to determine the differences in the characteristics between the subjects in the groups of 110m and 400m hurdlers and between the hurdlers and the controls (students).

Statistical significance was set at $p < 0.05$. A Pearson correlation analysis was used to determine the relationships between the anthropometric parameters and the results (points) in the hurdle runs. Hotteling's principal components factor analysis followed by varimax rotation was used to reduce the number of variables. Only those components yielding eigenvalues greater than 1.0 were considered meaningful. In the regression analysis most loading parameters from three factors (see factor analysis) were utilized. Pearson correlation between the factor scores and the performance scores was used to investigate the relationship between the results in hurdle races and groups of anthropometric variables.

Results

Basic parameters

On average, the Polish hurdlers were taller than the students (184.3 ± 4.3 vs. 177.3 ± 6.4 cm, $p < 0.01$). The mean stature of the Olympic Games and World Championships finalists in the years 1991-1999 was 186.9 ± 4.9 cm, (400 m) $p < 0.01$ (Table 2 and Table 3).

As observed in the World Championships and Olympic Games 1991-1999, the Polish 110-m Małgorzata hurdlers were taller than the 400-m Małgorzata hurdlers (185.2 ± 3.5 vs. 183.5 ± 4.8 cm, Table 3). The 110-m hurdlers were heavier than the 400-m hurdlers (in Poland 77.0 ± 5.9 vs. 74.4 ± 4.9 kg, in the world 78.3 ± 4.7 vs. 76.9 ± 5.1 kg). There were no significant differences in BMI between the Polish and the world athletes (Table 2).

Table 2. Anthropometric characteristics of World Championships and Olympic Games finalists 1991-1999 (n = 56) and best Polish hurdlers (n = 60) (mean ± SD)

Parameter	Area	110 m hurdles	400 m hurdles
Stature (cm)	World[1)]	186.9 ± 5.8	184.4 ± 4.9**
	Poland	185.2 ± 3.5	183.5 ± 4.8
Body mass (kg)	World[1)]	78.3 ± 4.7	76.9 ± 5.1
	Poland	77.0 ± 5.9	74.4 ± 4.9[a]
BMI	World[1)]	22.4 ± 1.4	22.6 ± 1.0
	Poland	22.4 ± 1.3	22.1 ± 0.9

1) – according to Mappa and Quercetani (1999)
*** - difference between 110 and 400 m hurdlers p < 0.01*
a) – difference between Polish and World hurdlers p < 0.05

Anthropometric parameters

The anthropometric variables revealed that the Polish hurdlers were taller and had longer parts of the body (thigh, calf, foot) in comparison with their counterparts from the students control group ($p < 0.001$). The Polish hurdlers were found to have a shorter trunk, smaller transverse chest and biiliocristal breadth (Table 3). There were no significant differences in any length and breadth anthropometrics in the groups of 110-m and 400-m hurdlers.

Among the girth anthropometrics the arm girth (relaxed) was larger in the students ($p < 0.01$). Significant differences between the hurdlers and the controls were found in thigh and calf girths ($p < 0.05$). We found differences in the chest girth only between both groups of hurdlers. The 400-m hurdlers' chest girth was 2.07 cm larger on average ($p < 0.05$). There were no statistical differences between the hurdlers' skinfolds, however, the 400-m runners had a higher sum of 7 skinfolds (47.6 ± 10.9 vs. 44.2 ± 8.6 mm). The athletes had lower skinfolds at five sites (subscpular, triceps, abdomen, chest and thigh), the controls at two sites (calf and suprailiac). Most differences in fat distribution were in the thigh skinfold (students 7.3 mm, hurdlers 9.3 mm, $p < 0.001$).

Body composition

There were significant differences in LBM and muscle mass between the hurdlers and the controls ($p < 0.001$). The students had a higher percentage of relative and absolute BF ($p < 0.001$). There were no significant differences between the groups of hurdlers in BF, LBM and muscle mass.

The somatotypes of hurdlers and the controls showed some differences. The endomorphic component was the same (1.9 ± 0.7), but the hurdlers had significantly lower mesomorphy ($p < 0.01$). The Polish hurdlers' somatotype was 1.9 – 3.5 – 3.8. The 110-m hurdlers had a higher mesomorphic component than the sprinters in the 400-m hurdles (3.7 ± 0.8 vs. 3.4 ± 0.7), but this difference was not statistically significant (Table 3).

Table 3. Statistics of anthropometric measures, body composition estimates and somatotype components of Polish hurdlers (mean ± S.D.)

Variable	Hurdlers (n = 60)	Students (n = 60)	110 m hurdles (n = 30)	400 m hurdles (n = 30)
Stature (cm)	184.3 ± 4.3***	177.3 ± 6.4	185.2 ± 3.5	183.5 ± 4.8
Leg length (cm)	97.7 ± 3.9**	88.8 ± 4.2	98.1 ± 3.4	97.4 ± 4.4
Trunk length (cm)	53.2 ± 2.8	55.8 ± 3.1	53.9 ± 3.0	52.5 ± 2.5
Arm length (cm)	81.4 ± 4.9**	79.4 ± 3.3	81.5 ± 2.9	81.4 ± 6.4
Thigh length (cm)	45.5 ± 6.6***	41.8 ± 2.8	46.2 ± 2.7	44.7 ± 2.8
Calf length (cm)	45.0 ± 2.4***	40.3 ± 2.7	45.0 ± 1.9	45.0 ± 2.8
Foot length (cm)	27.7 ± 1.1***	26.3 ± 1.3	27.8 ± 0.9	27.6 ± 1.2
Biacromial breadth (cm)	40.6 ± 1.9*	39.6 ± 1.6	40.9 ± 1.8	40.2 ± 1.9
Transverse chest (breadth) (cm)	29.1 ± 1.6	28.3 ± 2.0	28.9 ± 1.5	29.3 ± 1.7
Chest depth (cm)	19.2 ± 1.6***	20.7 ± 1.6	19.3 ± 1.6	19.2 ± 1.6
Biiliocristal breadth (cm)	28.8 ± 1.1	29.6 ± 1.5	29.1 ± 1.3	28.5 ± 1.6
Chest girth (cm)	96.4 ± 4.2	95.2 ± 6.0	95.0 ± 4.8	97.7 ± 3.0[a]
Hip girth (cm)	95.8 ± 3.7	94.2 ± 4.2	96.4 ± 4.5	95.2 ± 2.6
Abdominal girth (waists) (cm)	78.6 ± 3.5	79.8 ± 4.1	78.2 ± 3.8	79.1 ± 3.1
Arm girth (cm)	27.9 ± 1.8**	29.1 ± 2.3	27.9 ± 2.1	27.9 ± 1.6
Thigh girth (cm)	57.0 ± 2.8*	55.8 ± 2.2	57.0 ± 3.3	57.0 ± 2.1
Calf girth (cm)	38.0 ± 1.6*	37.3 ± 2.1	38.3 ± 1.7	37.8 ± 1.6
Subscapular skinfold (mm)	7.5 ± 1.4	7.6 ± 1.9	7.7 ± 1.8	7.3 ± 1.2
Triceps skinfold (mm)	5.4 ± 1.4**	6.3 ± 2.0	5.3 ± 1.5	5.4 ± 1.4
Abdominal skinfold (mm)	5.9 ± 1.6**	8.4 ± 3.0	6.3 ± 1.8	5.6 ± 1.3
Arm skinfold (mm)	7.0 ± 1.7	7.8 ± 2.4	7.4 ± 1.9	6.6 ± 1.5
Chest skinfold (mm)	7.3 ± 2.1***	9.3 ± 3.1	7.6 ± 2.2	7.0 ± 2.0
Front skinfold (mm)	5.2 ± 1.8	5.1 ± 1.5	5.2 ± 1.9	5.1 ± 1.7
Calf skinfold (mm)	7.7 ± 3.4	6.6 ± 2.8	8.1 ± 3.7	7.2 ± 3.1
Suprailiac skinfold (mm)	46.0 ± 8.4	48.1 ± 11.1	47.6 ± 10.9	44.2 ± 8.6
Sum of 7 skinfold (mm)				
Biepicondylar humerus (cm)	7.4 ± 0.5**	7.2 ± 0.5	7.5 ± 0.5	7.3 ± 0.4
Biepicondylar femur (cm)	9.9 ± 0.4**	9.2 ± 0.4	10.0 ± 0.5	9.8 ± 0.4
Body mass (kg)	75.7 ± 5.5	74.2 ± 7.5	77.0 ± 5.9	74.4 ± 4.9
Body fat (%)	8.5 ± 1.4***	13.2 ± 2.0	8.6 ± 1.6	8.3 ± 1.2
Body fat (kg)	6.4 ± 1.2***	9.9 ± 2.1	6.6 ± 1.4	6.2 ± 1.0
Lean body mass (%)	91.5 ± 1.4***	86.8 ± 2.0	91.4 ± 1.6	91.7 ± 1.2
Lean body mass (kg)	69.3 ± 5.1***	64.4 ± 6.1	70.4 ± 5.7	68.2 ± 4.5
Muscle mass (%)	64.6 ± 4.3***	42.4 ± 2.9	63.8 ± 4.2	65.4 ± 4.2
Muscle mass (kg)	48.9 ± 5.2***	31.5 ± 3.9	49.2 ± 6.1	48.7 ± 4.3
Body mass index	22.3 ± 1.1***	23.6 ± 1.9	22.4 ± 1.3	22.1 ± 0.9
Endomorphy	1.9 ± 0.7	1.9 ± 0.7	2.0 ± 0.7	1.9 ± 0.6
Mesomorphy	3.5 ± 0.8*	3.9 ± 1.1	3.7 ± 0.8	3.4 ± 0.7
Ectomorphy	3.8 ± 0.6**	2.8 ± 1.0	3.7 ± 0.7	3.8 ± 0.6

[1)] – body fat (%) according to Piechaczek (1976)
[2)] – muscle mass according to Martin, Spenst, Drinkwater and Clarys (1990)
Significant differences between hurdlers and students: *- $p < 0.05$, ** - $p < 0.01$, *** - $p < 0.001$
Significant differences between 110 and 400-m hurdles: [a] – $p < 0.05$

Correlation analysis

The correlation between the hurdle performance (points) and selected anthropometric, somatic and body composition parameters is presented in Table 4.

The highest ($p < 0.001$) relationships for the group as a whole (n = 60) were observed for muscle mass in kg (0.62), % LBM (0.53), thigh girth (0.49), stature (0.48), arm girth (0.46), body mass (0.45) and transverse chest breadth (0.41). Important body composition parameters for hurdler athletes consisted also of leg and calf lengths ($r = 0.40$. vs. 0.34. $p < 0.05$) and minimum of thigh skinfold ($r = -0.33$. $p < 0.01$).

There were no significant correlations between length, breadth and girth variables and hurdle performances.

Between the two groups of hurdlers significantly higher values were observed in the 110-m runners. The most important ($p < 0.001$) anthropometric parameters influencing performance in the 110-m hurdling event were found in muscle mass (0.72), LBM (0.68), stature (0.64), thigh and arm girths (0.62 and 0.56) and body mass (0.57). In the group of 400-m hurdles significant correlations ($p < 0.05$) were obtained in five variables (stature, foot length, chest breadth, biepicondylar humerus and muscle mass).

Table 4. Pearson correlation coefficient between anthropometric variables, somatotype and body composition characteristics and results in 110 or 400 m hurdles.

Parameters	Hurdlers (n = 60)	Students (n = 60)	110 m hurdles (n = 30)	400 m hurdles (n = 30)
Stature (cm)	0.48***	0.05	0.64***	0.37*
Leg length (cm)	0.40**	-0.11	0.54**	0.25
Trunk length (cm)	0.04	0.07	0.33	-0.11
Arm length (cm)	-0.05	0.07	-0.07	-0.05
Thigh length (cm)	0.19	-0.11	0.30	-0.01
Calf length (cm)	0.34**	0.07	0.41*	0.32
Foot length (cm)	0.28	0.14	0.23	0.39*
Biacromial breadth (cm)	0.26*	0.00	0.34	0.15
Transverse chest (breadth) (cm)	0.41***	0.18	0.38*	0.46*
Chest depth (cm)	0.25	0.04	0.26	0.22
Biiliocristal breadth (cm)	0.16	0.02	0.23	0.02
Chest girth (cm)	0.31*	-0.06	0.33	0.33
Hip girth (cm)	0.31*	0.06	0.37*	0.14
Abdominal girth (waists) (cm)	0.43**	0.06	0.50**	0.10
Arm girth (cm)	0.46***	0.03	0.56***	0.25
Thigh girth	0.49***	0.04	0.62**	0.20
Calf girth (cm)	0.29*	0.06	0.47**	0.03
Triceps skinfold (mm)	-0.10	-0.26*	-0.03	-0.20
Abdominal skinfold (mm)	-0.21	-0.14	-0.21	-0.25
Front thigh skinfold (mm)	-0.33**	-0.10	-0.35	-0.33
Calf skinfold (mm)	-0.24	-0.36**	-0.27	-0.20
Sum of 7 skinfold (mm)	-0.17	-0.20	-0.16	-0.23
Biepicondylar humerus (cm)	0.10	0.14	-0.08	0.39*
Biepicondylar femur (cm)	0.25	0.08	0.19	0.31
Body mass (kg)	0.45***	0.02	0.57***	0.26
Body fat (%)	-0.15	-0.42***	-0.14	-0.19
Body fat (kg)	0.03	-0.32*	0.11	-0.07
Lean body mass (%)	0.15	0.42***	0.14	0.19
Lean body mass (kg)	0.48***	0.06	0.68***	0.30
Muscle mass (%)	-0.14	0.15	-0.38*	0.11
Muscle mass (kg)	0.62***	0.09	0.72***	0.42*
Body mass index	0.21	0.01	0.33	-0.04
Endomorphy	-0.06	-0.03	-0.04	0.04
Mesomorphy	0.00	0.06	-0.05	0.23
Ectomorphy	0.01	0.02	-0.11	0.06
Body mass index	0.21	0.01	0.33	-0.04

* - $p < 0.05$, ** - $p < 0.01$, *** - $p < 0.001$

Factor analysis

The basic anthropometric variables were used in the principal component analysis. Factor analysis extracted three meaningful factors accounting for 52.4% of the overall variance (Table 5). The first factor (20.5% total variance) clearly represented all girth variables (loading from 0.65 to 0.83). Representative variables: chest, hip, abdominal, arm, thigh, calf girths and body mass. This factor could be called the 'muscle factor'. The second factor was composed of skinfolds (loading from 0.62 to 0.83). This factor was termed "fat factor" and explained a further 17.7% of common variance. The main variable: abdominal, chest, front thigh, calf and suprailiac skinfolds. The third factor ("stature factor") was mainly characterised by lengths, especially stature (0.81), leg (0.80), calf (0.72) and foot (0.73). Correlations between the hurdle performance and the three factors yielded 0.45 ($p < 0.01$), -0.24 and 0.27 ($p < 0.05$).

Regression analysis

To find the optimal variables combination in order to predict the results in hurdle performance we used the anthropometric parameter from three factors. The regression equations suggested that the main predictors were: stature (first factor), arm, thigh and chest girths (second factor) and thigh or calf skinfolds (third factor). In the case of the whole group of hurdlers (110 m and 400 m) the total performance variance explained was 39-44% ($F = 79.30 – 82.79$. $p < 0.001$). The best independent variables consisted of stature, thigh girth and thigh skinfold (Table 6). The optimal regression equation for the 110m hurdlers accounted for 59% of the variance in the hurdle run ($F = 12.07$. S.E. = 81.00 points/ 0.56s. $p < 0.001$). The combination of the three variables in the group of 400m hurdles yielded lower coefficients ($R^2 = 0.30$. S.E. = 76.34 points/1.85s. $F = 3.74$. $p < 0.05$).

Table 5. Hotteling's factor analysis followed by a rotation varimax of basic anthropometric variables.

Variables	Factor		
	1[1)]	2	3
Stature	.31	-.18	**.81**
Trunk length	-.12	.54	.24
Arm length	.12	.01	-.42
Thigh length	.31	-.35	.22
Calf length	.14	.03	**.75**
Foot length	.02	-.13	**.79**
Biacromial breadth	.30	-.22	.46
Transverse chest breadth	.54	-.38	.32
Chest depth	.26	.09	.22
Biiliocristal breadth	.64	.16	.63
Chest girth	**.83**[2)]	-.41	-.02
Hip girth	**.69**	-.04	.08
Abdominal girth	**.65**	.16	.11
Arm girth	**.78**	.08	.05
Thigh girth	**.83**	.05	.15
Calf girth	**.80**	.15	.08
Subscapular-skinfold	.36	.64	-.13
Triceps skinfold	.15	.53	-.17
Abdominal skinfold	.09	**.75**	-.11
Chest skinfold	.34	**.69**	-.06
Front thigh skinfold	-.05	**.74**	-.06
Calf skinfold	-.22	**.79**	.12
Suprailiac skinfold	.15	**.83**	.05
Biepicondylar humerus	.41	.22	.43
Biepicondylar femur	.40	-.29	.41
Body mass	**.69**	.00	.55
Common variance	20.5%	17.7%	14.2%

1) Factor 1 – "muscle factor"
Factor 2 – "fat" factor
Factor 3 – "stature" factor
2) **.75** (representative variables) – loading higher than .65

Table 6. Multiple – regression equations predicting performances in hurdle races

Dependent variable	Intercept	Independent variables	R	R^2	S.E. (points/s)	F	P
y_1	-820.95	$+ 0.320x_1 + 0.369x_2 – 0.31x_6$	.65	.43	80.19 p.	13.81	0.001
y_1	-1036.66	$+ 0.296x_1 + 394x_3 – 0.31x_6$	.66	.44	79.30 p.	14.53	0.001
y_1	-1276.07	$+ 0.360x_1 + 0.334x_5 – 0.28x_6$	.64	.41	81.27 p.	12.96	0.001
y_1	-1076.99	$+ 0.295x_1 + 0.391x_3 – 0.22x_7$	.62	.39	82.78 p.	11.81	0.001
y_2	-2557.35	$+ 0.469x_1 + 0.438x_2 – 0.12x_7$	.77	.59	80.09 p. /0.55 s	12.55	0.001
y_2	-2058.11	$+ 0.359x_1 + 0.442x_3 – 0.15x_6$	.75	.56	83.18 p. /0.56 s	11.00	0.001
y_3	-539.59	$+ 0.341x_1 + 0.235x_5 – 0.38x_6$	.57	.32	75.21 p. /1.83 s	4.17	0.05
y_3	-579.20	$+ 0.355x_1 + 0.178x_4 – 0.33x_6$	.55	.30	76.47 p. /1.86 s	3.74	0.05

Discussion

There are no significant differences in relation to the two basic anthropometric variables (stature and weight) between the Polish and world class 110-m hurdlers (Table 2) apart from the fact that the Polish 400-m hurdlers were lighter than the world runners ($p < 0.05$).

The study proved that the 110-m hurdlers were taller and heavier than the 400-m hurdlers. This finding is in accord with the results of a similar investigation conducted by Kostial (1978) as well as Kostial and Matousek (1979) who investigated Slovakian hurdlers. The 110-m hurdlers (mean ± SD. 14.75 ± 0.45 s) were 183.88 ± 4.35 cm tall and 74.63 ± 4.81 kg in weight (Kostial, 1978). The best runners in 400 m event (53.66 ± 1.78) were shorter (181.3 ± 4.59 cm) and lighter (72.3 ± 0.93 kg) (Kostial & Matousek, 1979).

The differences between the 110- and 400-m hurdlers were identified by Tanner (1964) over 30 years ago. The average stature and body mass of five 28-year-old hurdlers in the studies conducted by Whiters et al. (1987) yielded 179.9 ± 0.7 cm and 66.8 ± 0.9 kg, respectively. The finalists in the Rome Olympics (both distances) were about 4-cm shorter than contemporary hurdlers. Body mass differences (above 6 kg) related only to the 400-m hurdlers. This considerable difference was related to changes in the 400-m hurdles training system.

Endurance-technical training (Farmer, 1970) which was predominant in the 1960s was replaced by strength-technical training (Alejo, 1993; Iskra, 1999).

The anthropometric length variables showed that the basic differences between the hurdlers and the controls concerned leg and trunk lengths. Therefore, in the selection process of potential hurdlers these parameters are often taken into account (Kostial. 1978; Kostial & Matousek, 1979; Tabacznik, Timoszenko & Chalilov, 1986; Sparrey, 1997). Tanner (1964) viewed the ideal hurdler as having long legs in comparison to the trunk. This type of hurdlers was still predominant at the end of the 1990s.

The same circumference size of the thigh girth in both groups of hurdlers indicates that the distance 400-m hurdles presumably becomes similar with regard to the training structure for 110-m hurdles (Alejo, 1993; Iskra, 1999). The strong physique of 400-m hurdlers is confirmed by their larger chest girth ($p < 0.05$) in comparison with the 110-m hurdlers. Skinfolds in the group of sprinters and hurdlers constitute an important factor in monitoring sports training (Sparrey, 1997). Training of the same motor character probably resulted in similar fat distribution in both groups of hurdlers (110 m and 400 m). It is likely that hurdle training caused a significant decrease in the athletes' thigh fat tissue (the difference between the hurdlers and the controls' front thigh skinfolds was at $p < 0.001$). In this case thigh girth, thigh length (positive) and thigh skinfold (negative) were the most important anthropometric variables in the group of hurdlers.

In various studies, body composition was one of the most important markers of physical preparation. Athletic speed events (including hurdle runs) required maximizing LBM and muscle mass and minimizing %BF (McNeal, Pool & Sands, 1999). The calculations of %BF in sprinters and hurdlers were made in previous studies by means of different anthropometric estimations. In the study by Blount and associates (1990), the %BF of the best junior American sprinters ranged from 6.0 to 10.1% (mean 7.46%). Thorland et al.

(1981) and Withers et al. (1987) in small groups of sprinters and hurdlers obtained 8.3% BF. Sprinters' and hurdlers' % BF in other studies were 8-16% (Fleck, 1983), 10.3 (Mero, 1987) and 8.78 ± 1.82 (Piechaczek, 1995). Pipes (1977) observed %BF under 6% (hydrostatic weighing technique). Pipes (1977), Rivera and Navarez (1993), Krawczyk (1995) and Sinning (1996) suggested that sprinters and hurdlers had low %BF and high LBM as compared with the other trade-and-field events. Large differences between the hurdlers and the controls highlighted the important role of strength preparation in sprint training. In terms of the two (110 m and 400 m) distances, there were no statistical differences in muscle mass between the two groups of hurdlers. In athletics (including running events) meso and ectomorphic components of the somatotypes were dominant. Higher mesomorphy was typical for sprint events. higher ectomorphy for distance running (Tanner, 1964; de Garay et al., 1974; Carter, Aubry & Sleet. 1982). A lack of any statistically significant differences in the somatotypes between the 110-m and 400-m hurdlers was probably associated with the similar selection system and considerably related training approaches. It was difficult to find statistical differences between the investigated groups of hurdlers because at the end of the 1990s the training sessions of 110-m and 400-m hurdlers, (especially in the strength exercises) were similar. Correlation analysis showed that the dominant parameter in the hurdle runs (especially in 110 m) was muscle mass. Mainly in the 110-m hurdles. there were high relationships between limb girths and performance. The reason for this was probably the large amount of strength and power training in sprint events at the end of the 1990s (Blount et al., 1990; Alejo, 1990; Delecluse, 1997). Some of the simplest anthropometric selection parameters in hurdles were stature, leg length and body mass (Sparrey, 1997). In the combined group of Polish hurdlers these parameters were quite significant especially in the 110-m hurdles. Correlations with stature and leg length were stronger than in the previous study (Kostial, 1978). Different results were obtained in the study of Czech 400-m hurdlers (Kostial & Matousek, 1979). The relationships between performances and stature ($r = 0.44$, $p < 0.01$), leg length ($r = 0.51$, $p < 0.001$) and body mass ($r = 0.36$, $p < 0.05$) were stronger than in the Polish runners.

It is difficult to say what kind of somatotype is most important in hurdle runs. None of the three somatic components influenced the level achievements. There were negative relationships between the fatness and skinfolds and results in hurdle runs. However, only correlations with thigh skinfold ($n = 60$) were statistically significant ($p < 0.01$).

Three factors ("muscle", "fat" and "stature") separate three groups of anthropometric parameters of hurdlers. The "muscle" and "fat" factors are of importance over a many-year training cycle, the "stature" factor is particularly important at the stage of selection. Factor analysis conducted in a group of 41 female 100-m hurdlers allowed the identification of 6 factors including, apart from body composition parameters, tests of motor preparation (Czerkaszin, 1984). The sixth factor consisted of stature, leg length, hip girth and "special hurdle endurance" – the last one is fundamentally important in hurdlers. The correlations between hurdle performance and factor scores, obtained from principal factor analysis, indicate a different significance of the separated group of anthropometric variables. A significant correlation between the first factor and the hurdle performance ($p < 0.01$) demonstrates the considerable importance of musculature in hurdlers' preparation. A negative relationship was observed between the "fat" factor and the mark in hurdle runs ($r = -0.24$, $p < 0.066$). Although it seems that fat tissue is not propitious to supreme hurdle performances. it is not the most important factor as regards hurdlers' body composition (as is the case with middle- and long- distance runners). Claessens and associates (1994) found a statistically significant relationship ($r = -0.45$, $p < 0.01$) between the "fat development" factor and the performance in the 400 m run (within the modern pentathlon). An important role of the "stature" factor ($p < 0.05$) indicates that body height and leg length (indirectly) are the parameters of the morphological configuration of hurdlers which are conducive to obtaining top-class results in hurdle runs.

The results of the stepwise multiple regression analysis showed that three combined anthropometric variables (one variable from each factor) contributed 56-59% (110 m) and 30-32% (400 m) to hurdle run results. The remaining part of the hurdlers' training system depended on motor and coordination abilities. This was confirmed by the study of Kostial and Matousek (1979) where five anthropometric parameters contributed 31% to the results in the 400-m runs. The coefficient of determination shows that body composition is one of the most important areas of the system of selection and training in hurdle races. The regression equations suggested that stature (factor 1), thigh and arm (110 m) or chest and abdominal (400 m) girths (factor 3) and thigh and calf skinfolds (factor 2) were the most useful anthropometric parameters to predict hurdle performance. It is also important that fatness (thickness of skinfolds) was a negative predictor in that respect. Therefore, the measurement of skinfolds is a very popular way to monitor a training process in track-and-field (McNeal, Poll & Sands, 1999). The positive influence of stature and muscle mass could be utilized in continuous stages of training (from selection to high level performance). The study suggested that the anthropometric variables influenced more profoundly the results in the 110m (S.E. = 0.55 – 0.56 s) than in the 400m hurdling event (S.E. = 1.83 – 1.86s).

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ANTROPOMETRIJSKE KARAKTERISTIKE I USPJEŠNOST TRKAČA NA 110m I 400m S PREPONAMA

Sažetak

Uvod

Konačna izvedba i sportski uspjeh u atletskim disciplinama uvjetovani su genskom konstitucijom, ostvarenjem trenažnih ciljeva i zadataka te izvantrenažnim utjecajima iz okoline. Disciplina trčanja preko prepona (110m i 400m) za muškarce pripada skupini složenih atletskih disciplina. Uspješnost u trčanju preko prepona ovisi o motoričkim sposobnostima, tehnici i antropometrijskom profilu sportaša.

Cilj je ovog rada bio ispitati odnose između uspješnosti u trčanju preko prepona i pojedinih antropometrijskih i konstitucijskih obilježja muškaraca.

Metode

Uzorak ispitanika činilo je 60 poljskih preponaša i 60 studenata (AS ± S.D.: dob 21.3 ± 2.1 godina) Akademije tjelesnog odgoja iz Katowica.

Preponaši su bili podijeljeni u dvije skupine (N=30) prema disciplini u kojoj se natječu: preponaši na 110m (dobi 21.1 ±3.1 godina, visine 185.2 ±3.5 cm, tjelesne mase 77.0 ±5.9 kg te najboljeg vremena u trčanju preko prepona 14.5 ±2.1 s) i preponaši na 400m (dobi 20.9 ±1.9 godina, visine 183.5 ±4.8 cm, tjelesne mase 74.4 ±4.9 kg te najboljeg vremena u trčanju preko prepona 52.9 ±2.1 s). U te poduzorke bili su uključeni i europski prvak na 400m prepone iz 1998. godine te dva polufinalista olimpijskih igara (iz 1996. i 2000. godine) na 110m prepone. Ispitivanje je trajalo šest godina (od 1994. do 1999. godine). Kvaliteta preponaša na 100m i 400m (uspješnost) određena je prema atletskim tablicama rezultata (prema Spiriev i Kovacs, 1987).

Od antropometrijskih karakteristika izmjerene su longitudinalne mjere tijela (7), transverzalne mjere tijela (4), opsezi (6), kožni nabori (7) te tjelesna masa. Također su procijenjeni masa i postotak tjelesne masti (BF), nemasna tjelesna masa (LBM) i mišićna masa (MM), a određeni su i somatotipovi.

Podaci su analizirani *t*-testom za nezavisne uzorke, izračunati su Pearsonovi koeficijenti korelacija, provedena je faktorska analiza metodom glavnih komponenata (Hottelingova faktorska analiza) te stupnjevita regresijska analiza.

Rezultati i rasprava

Statistički značajne razlike između dviju skupina preponaša dobivene su za sve parametre longitudinalne dimenzionalnosti ($p<0.01$), nemasnu tjelesnu masu (LBM) i mišićnu masu (MM). Poljski preponaš je visok sportaš (184.3 cm), dugih je nogu (97.7 cm) i velikih mišićnih opsega (osobito natkoljenice i potkoljenice) s niskim postotkom masnog tkiva (vrijednosti kožnih nabora osobito su niske na natkoljenici, tricepsu i trbuhu). Rezultati ukazuju i na statistički značajnu povezanost ($p<0.01$) između uspješnosti trčanja preko prepona i tjelesne mase, mišićne mase, LBM (kg) te opsega trupa, ruku i natkoljenice. Veće vrijednosti korelacijskih koeficijenata dobivene su za grupu preponaša na 110m nego za one koji trče 400m prepone. Nijedan od tri utvrđena somatotipa ne utječe na rezultate u trčanju preko prepona. Analiza glavnih komponenata manifestni je prostor antropometrijskih varijabli i parametara tjelesne konstitucije sažela u tri dimenzije (STAS, MIŠIĆI i MAST) te je tako objašnjeno 52.4% zajedničke varijance. Faktor MIŠIĆI uključuje sve opsege, i to natkoljenice (projekcija -.83), prsa (.83), potkoljenice (.80) i ruke (.78). Koeficijent korelacije između ovog faktora i trčanja preko prepona iznosi 0.45 ($p<0.01$).

Najbolja kombinacija varijabli za predikciju rezultata u trčanju preko prepona uključuje: visinu, opseg natkoljenice i kožni nabor natkoljenice ($R=0.66$, $r^2=0.44$, $F=14.53$; $p<0.01$). Uspješnost predikcije ovom kombinacijom antropometrijskih varijabli veća je na uzorku preponaša koji trče 110m nego na uzorku preponaša na 400m ($R^2=0.59$ naspram $R^2=0.30$).

Zaključak

Dobiveni rezultati ukazuju na to da su antropometrijske varijable korisne za prognozu rezultata vrhunskih preponaša, osobito onih koji trče 110m s preponama.