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Original research article

THE PHYSICAL CHARACTERISTICS AND EXPLOSIVE STRENGTH OF SCHOOLCHILDREN

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Abstract. *The aim of this research was to determine the trend of relations between the system of body characteristics and the system of explosive strength variables. 402 participants aged 7 to 10 participated in this study. Seventeen measures for assessing anthropometric characteristics were applied and 4 tests for assessing explosive strength. Based on the obtained results on the relation of body characteristics and explosive strength it has been determined that there are significant relations of the two studied areas on the subsamples of participants aged 8, 9 and 10. The relations on the subsample of participants aged 7 are not statistically significant ($p<0.05$). When it comes to the trend of relations between the ages of 7 to 10 a permanent increase is evident, except for the subsample of participants aged 8, which shows a slight decline compared to the participants aged 7. Based on the cross-correlation of the two studied areas, it can be concluded that voluminosity and skinfolds measures appear to be negative (interfering) with tasks performance which highlights explosive leg strength in all the subsamples of participants.*

Key words: *relations, body characteristics, explosive strength.*

INTRODUCTION

Most motor skills and habits are developed and acquired during childhood from age 4 to 7, or in primary school children from the age of 7 to 11. During this period, the structure of motor space is built, based on the genetic and environmental factors that affect the overall growth and development of children (Bala, Kish & Popovic, 1996). It was found

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that some anthropometric dimensions have a largely innate character (e.g. longitudinal dimensionality of the skeleton), while others show a lower degree of innateness (e.g. volume and body mass, subcutaneous adipose tissue). It is similar with the motor skills of children, although they cannot be achieve differentiation in early childhood into separate and relatively independent motor skills (Bala, 1980).

Within the growth and development and the mutual relations of the morphological and motor dimensions, certain rules can be defined which depend on various factors (sex, age and physical activity). Types of motor skills and body composition are influenced by individual differences among children. Bala, Jaksic & Popovic (2009) suggest that the expression of motor skills depends, apart from the condition of the central nervous system, also on morphological dimensions.

Monitoring and comparing the results of the participants from seven to eighteen years of age, Kodrič (2000) found a significant correlation between morphological characteristics and motor abilities. Explosive strength as a part of the motor area is subject to genotype and phenotype influences. It represents the ability to invest the maximum energy in one movement in the shortest time possible (Malacko & Rađo, 2004, p.78). The coefficient of innateness in explosive strength is about 80% and its development should start very early (Nesić, 2002). There are different studies investigating the explosive strength of participants of different ages.

There are many studies which deal with the problem of the connection between motor ability and body composition. Biskanaki, Panagiotou, Papadopoulou, Spiridou, Gallos, Gill, et al. (2004) investigated the specific motor skills of children aged 8, male and female, depending on whether they were overweight or not. 195 boys and 216 girls were tested. Compared to the girls, the boys had higher scores on all the tests. Slightly obese children had better results than obese children on speed tests. Obese children had better results on throwing of medicine ball. The general conclusion of the authors is that boys are better than girls in motor abilities, and that obesity adversely affects motor abilities.

The study of Brunet, Chaput & Tremblay (2007) revealed that the BMI and waist circumference are negatively correlated with physical fitness. Research on physical fitness and body composition was conducted on a sample of 591 boys and 549 girls, aged 7, 8 and 10. Waist circumference was measured and BMI calculated. For the determination of physical fitness, the standing long jump was used, 1-min speed sit-ups and the speed shuttle run. They showed that the connections between the two studied areas were more pronounced in older children.

When comparing participants of different ages, absolute strength values increased with age (Holm, Fredriksen, Fosdahl & Vollestad, 2008). The aim of the research of Holm et al. (2008) was to establish the normative values of muscle strength, power and endurance, which are associated with age in healthy children aged 7 to 12. The connections between simple functional tests and isokinetic strength measures were investigated. The results showed that there was a significant and linear increase in strength in boys and girls from age 7 to 11, and a large variability within each age group. The correlation of the parameters of grip strength, vertical jump and strength of the quadriceps was expressed by coefficients of medium to strong levels.

Temfemo, Hugues, Chardon, Mandengue, & Ahmadi (2009) have shown that jumping performance increases during development. The aim of their study was to compare the performance of vertical jumping of boys and girls during development. Significant

correlations were obtained between average output strength and age, as well as between average output strength, body mass, and leg volume in each group of participants.

The results for explosive strength and speed are associated with age, as claimed in the study of Milanese, Bartolami, Bertucco, Verlato & Zancenaro (2010), which was conducted on a sample of 152 participants aged 6 to 12. The obtained results showed a significant correlation of better results in the tests of explosive strength and speed and anthropometric characteristics of older children. Body height and weight can have a positive impact on the explosive strength of the arms, and a negative effect on the static strength of the arms. The research results of Rodić (2012) showed that there is a correlation between anthropometric characteristics and motor abilities of 155 girls aged 7. On a sample of 97 boys aged about 11, Ivković (2008) applied a system of predictor variables (12 morphological and 12 motor) to show what their impact is on the variables of explosive strength. He obtained multiple positive and significant correlations on the basis of which it was concluded that morphological characteristics and motor skills are significant predictors for the explosive strength of children.

Bratić, Pavlović, Kostić & Pantelić (2012) have showed that anthropometric characteristics are significant predictors of explosive strength of the horizontal and vertical orientation in children aged 7-8. Proportion of the anthropometric characteristics in the horizontal jump ability ranges from 31% (for girls) to 38% (for boys), and vertical jump ability ranges from 33% (for boys) and 34% (for girls).

This study determined the relationship between the physical characteristics and explosive strength of the participants between the ages of 7 to 10, and what the trend of these relations is, depends on chronological age.

RESEARCH METHODS

The sample of participants

The sample included a total of 402 participants in primary schools in the city of Nis, all male, aged 7 to 10. The general descriptive parameters of the participants are shown in Table 1. Approval for conducting the testing was obtained from the parents, PE teachers and school principals. On the days of the measuring, all the participants were healthy. The measurements were taken on the premises of the schools, and were conducted by sports medicine doctors and physical education teachers.

Table 1 Characteristics of the sample (Mean ± SD)

	7 years (*n*=91)	8 years (*n*=100)	9 years (*n*=104)	10 years (*n*=107)
Age (years)	7.11 ± 0.41	8.14 ± 0.40	9.24 ± 0.46	10-09 ± 0.56
Body height (cm)	129.03 ± 5.35	135.35 ± 7.36	141.52 ± 7.27	147.23 ± 7.33
Body mass (kg)	30.26 ± 7.51	32.85 ± 7.53	38.09 ± 8.68	42.59 ± 10.03
BMI (kg/m^2)	18.05 ± 3.72	17.83 ± 3.26	18.87 ± 3.34	19.49 ± 3.41

Sample of measuring instruments

The parameters of physical characteristics were obtained by standard methods and instruments as described in the guidelines of the International Biological Program (IBP - Weiner & Lourie, 1969). The following were measured: Leg length, Arm length, Shoulder width, Pelvic width, Hips width, Middle chest circumference, Forearm circumference, Thigh circumference, Calf circumference, Upper arm skinfold, Back skinfold, Abdominal skinfold, Thigh skinfold and Calf skinfold.

For the determination of explosive strength, the following measuring instruments were applied: the Plyometric jump (Nazarenko, 2000); the Forward bend, Side bend, the toss right and left (Kostic, Djuraskovic, Pantelic, Zivkovic, Uzunovic et al., 2009); the Standing long jump (Kurelić et al., 1975). All of the tests used in this study showed good metric properties for the assessment of the explosive strength in children aged between 7-11 (Kostic, Đurašković, Pantelic, Uzunović Veselinovic et al., 2010).

Plyometric jump: The participant stands on a box 30cm high, jumps down with both legs and immediately jumps up, with his right hand touching the measuring tape on the wall. The result of the jump height is the difference between the largest height after the jump and the reaching height before climbing the box.

Bend sidebend jerk - right side: From the position facing the opposite direction of the throw, the participant, using both hands, throws a medicine ball weighing 3 kgs over his right shoulder back behind as far as he can. The result is the distance in decimetres from the place of the performance until the fall of the medicine ball.

Bend sidebend jerk - left side: From the position facing the opposite direction of the throw, the participant, using both hands, throws a medicine ball weighing 3 kgs over his left shoulder back behind as far as he can. The result is the distance in decimetres from the place of the performance until the fall of medicine ball.

Standing long jump: A barefoot participant jumps with both feet at the end of the reverse set springboards and jumps as far as he can away to the mat. The result is the distance in cm of the longest jump out of three jumps.

Methods of data processing

For data processing, the statistical package STATISTICA 7.0 for Windows (StatSoft. Inc., Tulsa, OK, USA) was use. The basic parameters of descriptive statistics (arithmetic mean and standard deviation) were calculated. To establish the correlation between the physical characteristics and the explosive strength canonical correlation analysis was applied. Trend of relations was determined based on the coefficient of determination of the first pairs of canonical factors. The level of significance for the correlation between physical characteristics and explosive strength was ($p<0.05$).

RESULTS

The plyometric jump (Table 3) is in a statistically significant negative correlation ($p <0.01$) with hip width in participants aged 7, 9 and 10. The bend-sideband and jerk right and left is in a statistically significant positive correlation ($p <0.01$) with most measures of longitudinal and transversal dimensionality only in participants aged 8. The standing long jump is in a negative correlation between pelvic width and hip width in participants aged 10.

Table 2 Basic parameters of descriptive statistics

	7 years	8 years	9 years	10 years
Leg length (cm)	70.17 ± 3.78	75.27 ± 4.20	79.44 ± 5.05	83.47 ± 5.10
Arm length (cm)	53.73 ± 2.44	56.95 ± 3.95	59.85 ± 3.51	62.93 ± 3.54
Shoulder width (cm)	28.29 ± 1.76	29.91 ± 1.87	30.83 ± 2.29	32.44 ± 2.18
Pelvis width (cm)	20.37 ± 1.75	21.70 ± 1.98	22.12 ± 2.03	23.25 ± 2.01
Hip width (cm)	21.83 ± 1.67	23.05 ± 1.87	23.88 ± 2.26	25.34 ± 2.22
Middle chest circumference (cm)	63.28 ± 6.07	65.16 ± 6.32	68.99 ± 7.88	71.90 ± 7.68
Forearm circumference (cm)	19.18 ± 2.72	19.42 ± 2.63	20.73 ± 2.95	22.22 ± 2.97
Thigh circumference (cm)	38.93 ± 4,87	39.82 ± 5.41	43.93 ± 6.33	45.74 ± 6.56
Calf circumference (cm)	27.20 ± 2.80	28.27 ± 2.78	29.70 ± 3.23	31.01 ± 3.27
Upper arm skinfold (mm)	12.56 ± 5.95	12.30 ± 7.37	13.41 ± 5.38	14.51 ± 5.66
Back skinfold (mm)	9.85 ± 6.93	9.03 ± 5.65	10.40 ± 6.15	10.70 ± 6.12
Abdominal skinfold (mm)	10.82 ± 7.30	11.00 ± 7.82	13.23 ± 8.28	14.83 ± 8.44
Thigh skinfold (mm)	17.41 ± 6.70	15.97 ± 6.32	18.65 ± 6.57	18.80 ± 5.91
Calf skinfold (mm)	15.92 ± 5.94	15.08 ± 5.45	15.11 ± 5.27	16.19 ± 4.73
Plyometric jump (cm)	13.64 ± 5.06	17.34 ± 5.46	18.99 ± 6.27	21.07 ± 6.07
Bend sidebend jerk - right side (dm)	27.34 ± 10.16	39.28 ± 10.80	47.82 ± 10.54	51.99 ± 15.21
Bend sidebend jerk - left side (dm)	26.95 ± 10.52	34.82 ± 10.34	42.45 ± 11.32	49.68 ± 13.78
Standing long jump (cm)	112.44 ± 21.41	122.41 ± 27.05	131.89 ± 20.55	143.21 ± 24.85

Table 3 Cross-correlations of longitudinal / transversal dimensionality measures and explosive strength

		Plyometric jump	Bend sidebend jerk - right side	Bend sidebend jerk - left side	Standing long jump
Body height	7 years	- 0.02	0.23*	0.26*	0.17
	8 years	- 0.03	0.41**	0.36**	0.12
	9 years	- 0.19	0.17	0.13	- 0.02
	10 years	- 0.14	0.16	0.15	0.02
Leg length	7 years	- 0.08	0.26	0.28**	0.15
	8 years	- 0.02	0.35**	0.33**	0.12
	9 years	- 0.22*	0.24*	0.23*	0.02
	10 years	- 0.14	0.16	0.13	0.08
Arm length	7 years	- 0.04	0.19	0.18	0.05
	8 years	0.14	0.37**	0.33**	0.24*
	9 years	- 0.23*	0.19	0.13	- 0.03
	10 years	- 0.11	0.10	0.09	0.10
Shoulder width	7 years	- 0.14	0.21	0.21	- 0.10
	8 years	- 0.06	0.37**	0.41**	0.07
	9 years	- 0.23*	0.14	0.07	- 0.06
	10 years	- 0.15	0.07	0.13	- 0.09
Pelvis width	7 years	- 0.21	0.07	0.10	- 0.13
	8 years	- 0.15	0.15	0.24*	-0.02
	9 years	- 0.43**	0.10	0.11	- 0.22*
	10 years	- 0.38**	- 0.07	- 0.04	- 0.37**
Hip width	7 years	- 0.34**	0.10	0.08	- 0.15
	8 years	- 0.19	0.26**	0.32**	-0.09
	9 years	- 0.28**	0.11	0.04	- 0.22*
	10 years	- 0.39**	- 0.14	- 0.11	- 0.33**

Legend: * - Level of significance .05; ** - level of significance .01

Table 4 Cross correlations of voluminosity and body mass measures and explosive strength

		Plyometric jump	Bend sidebend jerk - right side	Bend sidebend jerk - left side	Standing long jump
Body mass	7 years	- 0.28**	0.06	0.05	- 0.05
	8 years	- 0.20*	0.30**	0.37**	-0.15
	9 years	- 0.44**	0.08	0.02	- 0.35**
	10 years	- 0.36**	- 0.01	0.02	- 0.36**
Middle chest circumference	7 years	- 0.28**	0.10	0.12	- 0.14
	8 years	- 0.24*	0.31**	0.38**	-0.11
	9 years	- 0.43**	0.05	0.05	- 0.29**
	10 years	- 0.27**	0.00	0.05	- 0.25**
Forearm circumference	7 years	- 0.32**	0.05	0.06	- 0.16
	8 years	-0.27**	0.25**	0.34**	-0.19
	9 years	- 0.46**	- 0.02	- 0.12	- 0.41**
	10 years	- 0.36**	-0.09	- 0.04	- 0.38**
Thigh circumference	7 years	- 0.37**	0.04	0.04	- 0.21
	8 years	- 0.20*	0.18	0.31**	-0.14
	9 years	- 0.51**	0.04	0.02	- 0.35**
	10 years	- 0.39**	0.00	0.02	- 0.32**
Calf circumference	7 years	- 0.24*	0.10	0.09	- 0.12
	8 years	- 0.21*	0.27**	0.36**	-0.22*
	9 years	- 0.44**	- 0.04	- 0.04	-0.38**
	10 years	- 0.37**	0.01	0.03	- 0.38**

Legend: * – Level of significance .05; ** – Level of significance .01

Table 5 Cross-correlations of skinfold measures and explosive strength

		Plyometric jump	Bend sidebend jerk - right side	Bend sidebend jerk - left side	Standing long jump
Upper arm skinfold	7 years	- 0.29**	0.04	0.02	- 0.24*
	8 years	0.03	0.01	0.09	-0.14
	9 years	- 0.45**	- 0.02	-0.09	- 0.39**
	10 years	- 0.49**	- 0.18	- 0.17	- 0.55**
Back skinfold	7 years	- 0.37**	- 0.00	0.02	- 0.29**
	8 years	- 0.25**	0.24*	0.31**	-0.26**
	9 years	- 0.55**	- 0.14	-0.12	- 0.53**
	10 years	- 0.41**	- 0.07	- 0.07	- 0.55**
Abdominal skinfold	7 years	- 0.48**	- 0.03	- 0.05	- 0.30**
	8 years	- 0.30**	0.15	0.22*	-0.25**
	9 years	- 0.46**	- 0.03	-0.05	- 0.40**
	10 years	- 0.45**	- 0.15	- 0.15	- 0.55**
Thigh skinfold	7 years	- 0.44**	- 0.05	- 0.02	- 0.35**
	8 years	- 0.15	0.19	0.28**	-0.19
	9 years	- 0.41**	- 0.07	-0.10	- 0.40**
	10 years	- 0.34**	- 0.24*	- 0.21*	- 0.38**
Calf skinfold	7 years	- 0.34**	- 0.04	- 0.05	- 0.23*
	8 years	- 0 29**	0.15	0.22*	-0.26**
	9 years	- 0.39**	0.05	-0.02	- 0.23*
	10 years	- 0.54**	- 0.28**	- 0.29**	- 0.49**

Legend: * - Level of significance .05; ** - Level of significance .01

The plyometric jump is in a statistically significant negative correlation with all measures of voluminosity and body mass in participants aged 7, 8, 9 and 10. The bend sidebend jerk - right and left side is in a statistically significant positive correlation with most measures of voluminosity and body mass in participants aged 8. The standing long jump is statistically significantly correlated with all measures of voluminosity and body mass of the subsamples of participants aged 9 and 10 .

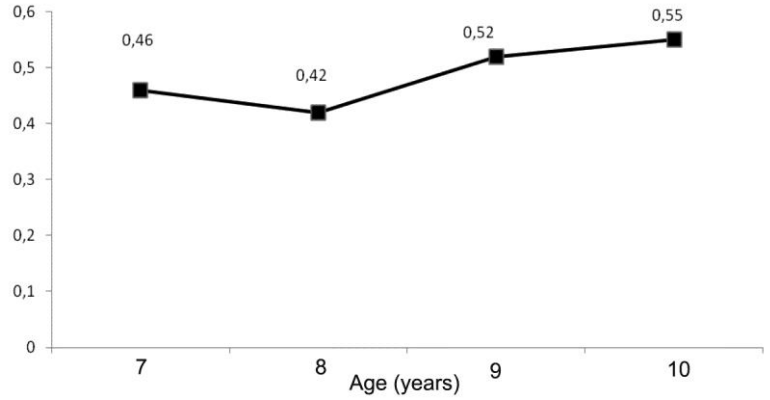
Correlations between the plyometric jump and most measures of skinfolds were statistically significant and positive in most of the subsamples of participants. The bend sidebend jerk - right side is in a statistically significant negative correlation with the calf skinfold in participants aged 10. The bend sidebend jerk - left side was in a statistically significant positive correlation ($p < 0.01$) with the back skinfold and thigh skinfold on the subsample of children 8 years old and in a statistically significant negative correlation ($p < 0.01$) with calf skinfold in the subsample of participants aged 10. The standing long jump is in a statistically significant negative correlation ($p < 0.01$) with most measures of skinfolds in all the examined subsamples of participants.

Table 6 Coefficients of the canonical correlation analysis between the physical characteristics and explosive strength

	Canonical R	Canonical R-sqr.	Chi-sqr.	df	p
7 years	0.68	0.46	84.23	68	0.089
8 years	0.65	0.42	109.08	68	0.001**
9 years	0.72	0.52	129.61	68	0.000**
10 years	0.74	0.55	130.95	68	0.000**

Canonical R – coefficient of canonical correlation,
Canonical R-sqr – determination coefficient of the pair of canonical factors,
Chi-sqr. – Barlett's Lambda test; dF – degrees of freedom; p – level of significance

The results of the canonical correlation analysis show that between the physical characteristics and explosive strength there is a statistically significant correlation with the subsamples of participants aged 8, 9 and 10. Graph 1 shows that between 7 and 8 years, there is a slight decrease in the relation of body features and explosive strength, and from 8 to 10 years of age the curve indicates a slight increase in relations.



Graph 1 The coefficients of determination of the first pairs of canonical factors

DISCUSSION

The study was conducted in order to determine the trend of relations between the physical characteristics system and the variables of the explosive strength system. Based on the results it was determined that there is a permanent increase in the development of the participants in accordance with their chronological age. The body mass index value indicates the smallest index in the participants aged 8 years, which is in line with a smaller increase in body mass as compared to other age groups. The results are compatible with the results of other studies showing lower BMI values for that age of participants (Milanese, Bortolami, Bertucco, Verlato, and Zancanaro, 2010).

Comparing the results of anthropometric measures among participants of different ages, a permanent increase was observed in all the parameters, except the skinfolds parameters in participants aged 8 years, who had lower values than the participants aged 7. However, these results differ somewhat from the results obtained by Popović (2010), which claims that boys have critical periods when there is a statistically significant increase in all measures for the assessment of body voluminosity from age 6 to 8, as well as around the age of 9.5. The author noted that these periods are characterized by a sudden weight gain in boys followed by an increase of body voluminosity and subcutaneous fat with a steady increase in body height. The reported differences can be attributed to the specificity of the participant sample. Regarding the parameters of explosive strength (Table 2), they all tend to increase from the age of 7 to 10, which is congruent with the research of Milanese et al. (2010), which has shown to enhance the motor ability in accordance with the different age periods from 6 to 12.

Between the anthropometric characteristics and explosive strength of the participants aged 7, the canonical correlation was not statistically significant. There is a small number of significant cross-correlations between the parameters of the two examined areas at this age, which are related to explosive leg strength, volume, and skinfolds. On the basis of the negative signs of the cross-correlations, it can be assumed that voluminosity and skinfold measures adversely affect the results of explosive leg strength.

In the participant sample aged 8, a statistically significant canonical correlation was obtained ($p = 0.001$). Between most measures of anthropometric characteristics and explosive strength as a whole, there are significant cross-correlations. Based on the sign of the cross-correlation, it is assumed that the anthropometric measures of volume and skinfolds adversely affect explosive leg strength, and most of the anthropometric measures in general (longitudinal, transversal, volume and skinfolds) have a positive effect on the explosive strength of the body, arms and shoulders. The overall growth of the sample of participants aged 8 is such that it favors the execution of tasks related to the explosive strength of the arms and shoulders. Molnar et al. (2008) have, by means of the canonical correlation analysis, found that the relations between the system of morphological variables and the system of basic motor variables are of moderate intensity.

Based on the obtained results, the authors concluded that the structure of the relation of the first canonical factor of the anthropometric variables system and the first canonical factor of the basic motor variables system shows that boys exhibiting higher skeleton dimensionality achieved better results on the tests for the assessment of the explosive strength, speed endurance and repetitive strength of the trunk flexor muscle, and vice versa.

In participants aged 9, a statistically significant canonical correlation was obtained (p = 0.000), which explained 52% of the common variance of the two sets of variables. The anthropometric measures for assessing the circular dimensionality of the body and measures of the subcutaneous adipose tissue have significant cross-correlations with the parameters of explosive leg strength (the plyometric jump and standing long jump). It is assumed that higher values of these parameters cause smaller values of explosive leg strength. In participants aged 10, one statistically significant canonical correlation was singled out (p = 0.000), which explained 55% of the common variance of the two sets of variables. The participants with lower volume and smaller amounts of subcutaneous fat achieve better results in the variables of the explosive leg strength. The obtained results of this study are partially compatible with the results of the research conducted by Biskanaki et al. (2004), Ivković (2008), Rodić (2012), Bratić et al. (2012).

CONCLUSION

Based on the obtained results on the relations of physical characteristics measures and explosive strength shown through the canonical correlation of the subsamples of participants and through the trend of relations, it can be concluded that there are significant relations between the two studied areas among the subsamples of participants aged 8, 9 and 10. The relations of the subsample of participants aged 7 are not statistically significant. When it comes to the trend of relations between the ages of 7 to 10, a permanent increase is evident, except for the subsample of participants aged 8, which shows a slight decline compared to the participants aged 7. Based on the cross-correlations of the two studied areas, it can be concluded that the voluminosity and skinfolds measures appear to be negative (interfering) for the performance of tasks which highlight explosive leg strength, in all the subsamples of participants.

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FIZIČKE KARAKTERISTIKE I EKSPLOZIVNA SNAGA DECE ŠKOLSKOG UZRASTA

Cilj ovog istraživanja bio je da se odredi trend u odnosima između sistema telesnih karakteristika i sistema varijabli eksplozivne snage. Ukupno je 402 ispitanika, starosti 7 do 10 godina, učestvovalo u istraživanju. Sedamnaest mera za određivanje antropometrijskih karakteristika primenjeno je, kao i četiri testa za procenu eskplozivne snage. Na osnovu dobijenih rezutata, odnosa između telesnih karakteristika i eksplozivne snage, utvrđeno je da postoje značajni odnosi između dve istraživane oblasti na podgrupi ispitanika starosti 8, 9 i 10 godina. Odnosi na primeru podgrupe ispitanika starosti 7 godina nisu statistički značanjni ($p<0.05$). Kada je u pitanju trend odnosa između ispitanika uzrasta od 7 do 10 godina, može se uočiti trajni porast, izuzev u slučaju ispitanika starosti 8 godina, gde se beleži blaži pad u poređenju sa ispitanicima starosti 7 godina. Na osnovu kros-validacije ispitivanih oblasti, može se zaključiti da su voluminoznost i mere kožnih nabora negativne, odnosno da ometaju izvođenje zadataka u kojima je dominantna eksplozivna snaga nogu, na primeru svih podgrupa ispitanika.

Ključne reči: *odnosi, telesne karakteristike, eksplozivna snaga.*