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CANONICAL RELATIONS BETWEEN ANTHROPOMETRIC AND MOTOR DIMENSIONS AMONG 12-YEAR-OLD STUDENTS

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SUMMARY

The aim of this empirical research was to examine the correlations between the groups of variables of anthropometric characteristics (16) and motor skills (21) among 154 students (AM = 11,53 SD = 1,12). The method of canonical correlation analysis was used to assess the correlation between the pairs of linear functions of predictor and criterion variables. The obtained canonical coefficients and canonical weights revealed that, with significance level ($p \leq 0,0,5$ or $p \leq 0,01$), there is a high level of correlation between linear combinations of the examined morphological characteristics and motor skills, where the explained mutual variance was 80% for the first and 33% for the second canonical function. The extracted relevant canonical pairs were interpreted hypothetically as "integrated morphological factor and the factor of static and repetitive strength and coordination", and the second one was interpreted as "morphological factor and the factor of explosive strength". The set of the first canonical morphological factor and the factor of static and repetitive strength, and coordination, is the maximum weight on the variables body mass, body height, forearm circumference, horizontal reverse plank, knee push-ups, and stick mobility, while the biggest contribution to the structure of the second canonical morphological factor and the factor of static and repetitive strength have variables 20m sprint with standing start, standing long jump, hand tapping and foot tapping.

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The obtained results of the analyzed bicomponent canonical model reveal more defined and predictable structure of the correlation between anthropometric characteristics and motor manifestations, and therefore give guidelines for planning, developing and controlling the training processes during physical education classes.

Key words: students, morphological variables, motor manifestations, canonical factors

INTRODUCTION

From the aspect of biological anthropology, anthropometric dimensions of students, as well as their motor manifestations, are relevant for examining the anthropological status of students (Ivanović, 2008[1]).

Morphological characteristics represent constitution as an organized and relatively constant set of characteristics which is formed from endogenetic and exogenetic factors, and is therefore responsible for the dynamic of growth and development of a body. They are defined as four-dimensional latent dimensions: longitudinal dimensionality of the skeleton – bone growth in length, transversal dimensionality – bone growth in width, circular dimensionality of a body – body mass and volume, and subcutaneous fat which includes total body fat. Morphological types are defined based on these latent dimensions, and regular measuring of anthropomorphic characteristics enables students to harmoniously develop motor skills and focus on the sport of their choosing (Ivanović, 2004)[2]. Motor skills include indicators of the development level of elementary movement dimensions which generate effective realization of movement (Ivanović i Ivanović, 2016)[3]. The necessity of identifying the laws of relations between motoric and morphological status enables the defining of the morphological characteristics variance which is responsible for the variability of motoric manifest reactions of preadolescents.

This study mentions representative researches that deal with the relationship between morphological and motoric make-up of preadolescent boys. Based on predictor (anthropometric) and criterion (motoric) variables, canonical statistical model was applied here and it generates morpho-motoric structure based on

[1] Мирољуб Ивановић, Таксономска анализа биомоторичких варијабли. *Зборник радова,* Сремска Митровица: Виша школа за образовање васпитача , стр. 58–69, 2008.

[2] Мирољуб Ивановић, *Човечје тело и физичке способности* (Ваљево: Графити, 2004b).

[3] Мирољуб Ивановић и Угљеша Ивановић, *Гимнастика за здраво дете од рођења до 3. године, недоношчад и децу са тешкоћама у развоју* (Ваљево: Ваљево-принт, 2016).

previously defined linear combinations of variables by domains and ranked according to the size of canonical weight (Tabachnick & Fidell, 2013)[4]. With the aim of realizing harmonious development of motor potential in preadolescence, it is necessary to identify the dominant anthropological components (primarily anthropometric) which can be influenced as they are not explored enough (Ivanović & Ivanović, 2015)[5]. The predecessors of the studies dealing with the problems of relations between morphological and motor variables were the studies conducted in former Yugoslavia (Gredelj et al., 1975[6]; Pejčić iet al., 2004[7]) which showed that during certain motor activities one type of constitution directly inhibits the realization of kinetic program, and on the other hand that same constitution can be seen as optimal during some other motor activity. The researches on the structure of the relations between anthropometric characteristics and motor skills of students indicate that there is relevant influence of biological development, namely anthropometric characteristics, on the prepubescents' performance on motor skills test, as it is stated in the study (Matić, 2006)[8].

The authors Pejčić and Malacko (1992)[9] extracted two canonical factors by applying 18 morphological and 18 motoric factors on the sample of boys no older than 11 years of age. The first canonical dimension shows high dimensionality of the skeleton, high body mass and volume, good coordination, repetitive strength and flexibility, and the second canonical dimension shows that students with less subcutaneous fat achieve better results in speed and explosive strength. The research by Jozića and Hrženjaka (2006)[10] shows that the first isolated pair of canonical factors, main motoric factors, accounts for 85% of mutual variance, and

[4] Barbara Tabachnick & Linda Fidell (*Using multivariate statistics*, Boston: Pearson. 2013).

[5] Miroljub Ivanović i dr., „Latente strktur der anthropometrischen variablen bei volleyballspielerinnen im alter von 12-14 jahren", *Физичка култура*, *69*(1), (2015): 14–24.

[6] Marijan Gredelj, i dr., „Model hijerarhijske strukture motoričkih sposobnosti. 1. rezultati dobijeni primjenom jednog neoklasičnog postupka za procjenu latentnih dimenzija", *Kineziologija, 5*(1-2), (1975): 7–82.

[7] Aleksandra Pejčić, i dr., „Kanoničke relacije morfoloških karakteristika i motoričkih sposobnosti u jedanaestogodišnjih dječaka", (*Zbornik radova, III. Kongres pedagoga fizičke kulture Jugoslavije*. Novi Sad: Fakultet fizičke kulture, str. 119, 1987).

[8] Radeno Matić, „Uticaj antropometrijskih karakteristika na izvođenje motoričkih testova kod dečaka i devojčica mlađeg školskog uzrasta", *Antropološki status i fizička aktivnost dece i omladine,* Novi Sad: Fakultet sporta i fizičkog vaspitanja, 2006: 149-154.

[9] Александра Pejčić i Julijan Malacko, „Kanoničke relacije morfoloških karakteristika i motoričkih sposobnosti u jedanaestogodišnjih dječaka" (*Zbornik radova, III. Kongres pedagoga fizičke kulture Jugoslavije*, Novi Sad: Fakultet fizičke kulture, str. 119,1987).

[10] Marijan Jozić i Miroslav Hrženjak, Relacije između morfoloških karakteristika i motoričkih sposobnosti učenika petog do sedmog razreda osnovne škole (*Zbornik radova 15. ljetne škole kineziologa Republike Hrvatske – Kvaliteta rada u područjima edukacije, sporta i sportske rekreacije*, Rovinj: Hrvatski kineziološki savez, str. 144-150, 2006).

is maximally determined by standing long jump, cyclical movement in various tempo lasting up to six minutes, and pull-up hold, while the first canonical factor within anthropometric variables is maximally characterized by the variables body height and abdominal skinfold (longitudinal factors and subcutaneous fat factors). The second bipolar canonical factor (coordination factor), with 74% of variability within specific motor variables, shows that the smaller amount of subcutaneous fat and smaller volume generate better results on motor ability tasks. The study conducted by Jerković (2011)[11],based on the set of 11 motor variables and 14 morphological variables, obtained three relevant canonical dimensions for boys age 13 to 14. The first canonical pair explained the link between longitudinal dimensionality of the skeleton and explosive strength such as sprint and throwing, and the second one explained the contribution of the meso-endomorph variables on the frequency of arm movement and the variables of various types of strength, while the third canonical pair shows negative contribution of the variable skinfold on the tests of explosive strength that include jumping and coordination. Earlier research (Ivanović, 2008)[12] determined the high probability of statistically significant correlation between the somatic development and motor skills task – biomechanical structure of movement in preadolescence which is very relevant for achieving athletic success. The findings of the study by Đorđević et al., (2014)[13] that used female participants and tested 16 anthropometric and 9 motor variables confirmed the extraction of canonical factors of anthropometric characteristics and motor skills. They show that body volume and subcutaneous fat make the completion of motor skills tasks that require lifting and moving body mass harder, while the higher values of the parameters of longitudinal dimensions contribute better performance of explosive strength of arms and legs, but make coordinated movement difficult.

The findings of the aforementioned researches showed that there is a difference in morphological structure of boys, and the different influence of certain morphological characteristics on their motor skills. Starting from theoretical postulates and previous findings, the aim of this transversal research was to determine the correlation, and its probability, between the manifested morphological characteristics and motor skills, then analyze the variance of the structural morpho-motoric model and the correlation between its latent dimensions in fifth grade elementary school students. Based on earlier research

1111 Zlatko Jerković, „Relacije morfoloških karakteristika i motoričkih sposobnosti učenika sedmog i osmog razreda osnovne škole“ (magistarski rad, Kineziološki fakultet, Split, 2011).

12 Miroljub Ivanović, „Kanoničke relacije latentnih morfološko-motoričkih varijabli učenica 5. razreda osnovne škole“ (*međunarodna naučna konferencija,* Beograd, Univerzitet u Beogradu, Fakultet sporta i fizičkog vaspitanja str. 137–144, 2008).

13 Marija Đorđević i dr., „The correlation between anthropometric characteristics and motor abilities in seven year old girls“, *Facta Universitatis, Series: Physical Education,12*(3), 2014: 251– 260.

and theoretical prediction, it is expected there to be statistically significant linear correlation between the manifested morphological characteristics and motor skills, as well as between the pairs of linear functions on a sample of 12-year-old male preadolescents.

METHOD

Participants

The pertinent sample included 154 fifth graders from thee elementary schools from Valjevo: "Vladika Nikolaj Velimirović", "Desanka Maksimović" and "Milovan Glišić". The average age of students was 11.53 (SD = 1.12). The sample included participants who voluntarily agreed to participate in the research, with parents' approval. Additional condition was that the students are not exempt from physical education and are healthy on the day of testing. Before the process began, the importance and the advantages of the research were presented to both children and their parents.

Measuring instruments for assessing anthropometric characteristics

The sample of morphological variables in this empirical research contains 13 anthropometric measurements. Their assessment is determined in accordance with the protocol established by Mišigoj-Duraković (2008)[14], which includes standard manifest anthropometric variables which assess four-component hierarchical model of fundamental *latent morphological dimensions*: *longitudinal dimensionality of the skeleton* – body height (AVIS), leg length – the height of anterior superior iliac spine (ADŽN) and arm length (ADŽR); *transversal dimensionality of the skeleton* – knee diameter (ADKL), elbow diameter (ADLK) and wrist diameter (ADRZ); *body volume and mass* - body height (AVIS), forearm circumference (AOPP), lower leg circumference (AOPT) and chest circumference in the normal position (AOGK); *subcutaneous fat* – upper arm skinfold (AKNN), back skinfold - subscapular skinfold (AKNL) and abdominal skinfold (AKNT).

Measuring instruments for assessing motor skills

The group of motor skills variables includes 21 standard composite motor skills test which assesses standard ***latent motor dimensions*** (Gredelj et al.,

[14] Marijeta Mišigoj-Duraković, *Kinantropologija.* Zagreb: Sveučilište u Zagrebu, Kineziološki fakultet, 2008.

1975)[15]: *coordination* – the polygon backwards (MRPOL), stick mobility (MKOSP) and side steps (MAKUS); *balance* – single leg stand on the balance bench with eyes open (MBU10), single leg stand on the balance bench with eyes closed (MBU1Z), both legs stand on the balance bench with eyes closed (MBU2Z); *flexibility* – twisting (MFISK), wide legged sitting forward bend (MFPRR), sidestep (MFBRS), movement frequency – hand tapping (MBTAP), foot tapping (MBTAN, and foot tapping against the wall (MBTAZ); *explosive strength* – standing long jump (MESDM), throwing a medicine ball from a prone position (MEBML), 20m sprint with standing start (ME20V); *static strength* – pull-up hold (MSVIS), horizontal reverse plank (MSHIL), squat hold (MSIZP), and *repetitive strength* – sit-ups (MRDTS), knee push-ups (MRSNK) and squats (MRPLČ).

Statistical analysis

In this cross-sectional study, descriptive and analytical statistics were used for data processing. The correlation between the manifested variables was assessed using the Pearson correlation method, with the starting degree of statistical significance being $p \leq .05$, while the correlation analysis was used for analyzing the correlations between predictor and criterion variables (Jendoubi *&* Strimmer, 2018)[16].

RESULTS

Tables 1 and 2 show the descriptive statistics parameters of morphological and motor variables.

Table 1. *Descriptive statistics and the data on the skewness and kurtosis index of morphological variables*

Variables	*Min*	*Max*	*AM*	*SD*	*Sk*	*Ku*
AVIS (cm)	129.84	174.90	155.08	6.45	.12	.18
ADŽN (cm)	72.96	102.95	90.17	4.73	.26	.37
ADŽR (cm)	56.92	79.14	67.33	3.86	.17	.25
ADKL ()	8.05	11.06	8.94	1.08	.40	.36

[15] Marijan Gredelj i dr., „Model hijerarhijske strukture motoričkih sposobnosti. 1. rezultati dobijeni primjenom jednog neoklasičnog postupka za procjenu latentnih dimenzija“, *Kineziologija, 5*(1-2), 1975: 7–82.

[16] Takoua Jendoubi i Korbinian Strimmer, "A whitening approach to probabilistic canonical correlation analysis for omics data integration*", BMC Bioinformatics, 20*(1), 2018: 15– 26.

ADLK (cm)	4.97	6.99	5.97	.55	.30	.28
ADRZ (cm)	3.96	5.69	4.98	.28	.09	.34
AMAS (0,1 kg)	27.96	81.88	46.93	10.12	.43	.38
AOPL (cm)	15.87	27.06	20.95	1.86	.14	.20
AOPT (cm)	23.95	41.97	31.86	2.92	.30	.42
AOGK (cm)	60.08	99.03	76.12	7.13	.14	.22
AKNN (0,2 mm)	5.78	32.99	14.96	6.85	.29	.33
AKNL (0,2 mm)	3.89	33.59	11.94	6.90	.47	.34
AKNT (0,2 mm)	4.89	50.98	20.08	10.13	.26	.43

Legend. AM = arithmetic mean; *SD* = standard deviation; *Sk* = standardized skewness; *Ku* = standardized kurtosis. The value of standard error *SE* with Sk is .15, and with *Ku* is .23.

Table 2. Descriptive statistics and the data on the skewness and kurtosis index of motor variables

Variables	*Min*	*Max*	*AM*	*SD*	*Sk*	*Ku*
MRPOL (0,1 s)	9.38	34.82	17.92	4.87	.14	.12
MKOSP (0,1 s)	2.48	7.30	4.58	1.13	.32	.27
MAKUS (0,1 s)	8.36	15.78	11.39	1.44	.43	.35
MBU10 (s)	1.19	16.28	3.89	2.94	.28	.35
MBU1Z (s)	.98	4.40	2.03	.57	.16	.37
MBU2Z (s)	.79	3.40	1.66	.52	.25	.46
MFISK (cm)	46.28	78.70	66.86	7.22	.43	.35
MFPRR (cm)	52.01	27.29	52.00	8.10	.11	.17
MFBRS (cm)	98.28	171.94	130.16	10.10	.36	.25

MBTAPR (freq)	23.29	38.71	28.59	3.06	.18	.42
MBTAN (freq)	12.29	22.28	16.88	1.85	.27	.16
MBTAZ (freq)	11.98	25.96	19.41	2.58	.42	.34
MESDM (cm)	89.95	192.43	144.04	12.66	.26	.22
MEBML (cm)	227.06	822.07	523.24	18.92	.42	.35
ME20V (0,1 s)	3.36	5.20	4.08	.28	.16	.18
MSVIS (0,1 s)	2.96	73.94	18.88	12.65	.33	.38
MSHIL (0,1 s)	.98	71.57	23.16	17.01	.32	.40
MSIZP (0,1 s)	9.96	119.03	89.00	36.72	.17	.15
MRDTS (freq)	11.96	62.94	37.96	7.95	.41	.24
MRSNK (freq)	3.97	62.96	24.04	12.08	.25	.32
MRPLČ (freq)	15	47.94	29.95	6.12	.23	.42

Legend. AM = arithmetic mean; *SD* = standard deviation; *Sk* = standardized skewness; *Ku* = standardized kurtosis. The value of standard error *SE* with Sk is .13, and with *Ku* is .25.

The obtained values of skewness and kurtosis coefficients of the variables for the assessment of morphological characteristics and motor skills show normal Gaussian distribution of data when compared to arithmetic mean, which enables further parametric steps in data processing (Tabachnick & Fidell 2013)[17].

Table 3 shows the results of statistical method of cross-correlation which uses cross-correlation coefficient to measure the degree of linear correlation between the pairs of variables of morphological characteristics (predictors) and variables of motor skills (criterion variables).

[17] Barbara Tabachnick i Linda Fidell, *Using multivariate statistics* (Boston: Pearson/Allyn & Bacon, 2013).

Table 3. Cross-correlation between the examined morphological and motor variables

Variables	AVIS	ADŽN	ADŽR	ADKL	ADLK	ADRZ	ATMA	AOPL	AOPT	AOGK	AKNN	AKNL	AKNT
MRPOL	**0.45**	**0.40**	**0.33**	**0.38**	**0.31**	0.05	**0.60**	**0.44**	**0.56**	**0.52**	**0.58**	**0.62**	**0.69**
MKOSP	0.18	0.15	0.17	**0.30**	0.19	0.13	**0.39**	**0.40**	**0.38**	**0.54**	**0.50**	**0.54**	**0.50**
MAKUS	0.10	0.07	0.05	0.01	0.09	0.02	0.20	0.18	**0.24**	0.16	**0.32**	**0.40**	**0.37**
MBU10	**-.34**	**-.29**	**-.30**	-.13	-.18	-.08	**-.30**	**-.32**	**-.29**	**-.33**	**-.30**	**-.29**	**-.30**
MBU1Z	**-.30**	-.21	-.18	-.20	**-.26**	-.06	**-.30**	-.11	-.20	**-.24**	-.20	-.17	-.15
NBU2Z	-.18	-.20	-.19	-.09	-.11	-.05	-.20	-.08	-.17	-.14	-.10	-.08	-.09
MFISK	0.20	0.18	0.20	0.19	0.17	**0.30**	**0.32**	0.19	0.18	**0.30**	0.03	0.16	0.06
MFPRR	0.18	0.10	0.21	0.18	0.09	**0.30**	**0.30**	**0.25**	**0.27**	**0.30**	0.08	0.14	0.06
MFBRS	**0.31**	**0.29**	**0.27**	0.19	0.08	**0.30**	0.17	0.13	0.05	0.03	-.03	-.06	-.22
MBTAR	-.03	-.06	-.01	0.06	-.07	-.01	-.20	-.04	-.16	-.05	-.20	-.23	-.17
MBTAN	-.08	-.11	-.08	-.12	-.09	-.03	-.21	-.06	-.18	-.03	-.20	-.21	-.20
MBTAZ	-.12	-.10	-.09	-.20	-.08	0.08	-.16	-.03	-.12	-.05	-.18	-.21	-.13
MESDM	-0,08	-0,07	-0,06	-0,20	-0,09	0,01	**-0,32**	**-0,30**	**-0,40**	**-0,34**	**-0,48**	**-0,53**	**-0,50**
MEBML	**0.50**	**0.40**	**0.38**	**0.41**	**0.39**	**0.38**	**0.35**	**0.51**	**0.44**	**0.49**	0.18	0.13	**0.30**
ME20V	0.10	0.09	0.11	0.18	0.16	0.05	**0.36**	**0.29**	**0.29**	**0.40**	**0.49**	**0.58**	**0.55**
MSVIS	**-.42**	**-.41**	**-.40**	**-.50**	**-.43**	-.17	**-.60**	**-.49**	**-.60**	**-.59**	**-.60**	**-.50**	**-.60**
MSHIL	-.03	-.05	-.02	-.10	0.05	0.09	-.08	-.01	-.09	-.11	-.09	-.07	-.15
MSIZP	**-.30**	**-.33**	-.21	**-.30**	**-.30**	**-.31**	**-.40**	**-.28**	**-.29**	**-.40**	**-.39**	**-.38**	**-.40**
SIZP													
RSNK	**-.28**	**-.27**	**-.29**	**-.30**	-.19	0.09	**-.40**	**-.29**	**-.19**	**-.30**	**-.29**	**-.29**	**-.30**
RPLČ	**-.49**	**-.49**	**-.46**	**-.38**	**-.37**	**-.28**	**-.52**	**-.40**	**-.39**	**-.38**	**-.39**	**-.50**	**-.40**

Annotation: correlations in bold have the significance of $p \leq .05$

Reviewing the matrix of cross-correlation, one can see the statistically significant linear correlation between most pairs of variables on the level of statistical significance of $p \leq .05$. The obtained correlations are of low and moderate intensity, positive or negative direction, and range from .24 to .69.

The relationship between the two sets of variables (morphological and motor variables), on this sample of students, was determined by using the multivariate canonical correlation analysis. The value over .30 was taken in the interpretation of the significance of the correlation between variables and canonical factors (Table 4).

Table 4. *Statistical significance, percentage of explained variance and the structure of canonical factors*

Rc	.91	.69			
Rc^2	.80	.33			
χ^2	601.27	396.15			
p	.01	.05			
Morphological variables	**CAN** 1	**CAN** 2	**Motor variables**	**CAN** 1	**CAN** 2
AVIS	.87	.36	MKPOL	.61	.72
ADŽN	.83	.34	MKOSP	.69	.68
ADŽR	.81	.32	MAKUS	.61	.70
ADKL	.78	.25	MBU10	-.42	-.10
ADLK	.70	.41	MBU1Z	-.31	.-01
ADRZ	.62	.23	MBU2Z	-.23	.07
ATMA	.90	.17	MFISK	.30	-.09
AOPL	.85	.05	MFPRR	.19	.20
AOPT	.80	.10	MFBRS	.32	.51
AOGK	.79	.01	MBTAR	.06	.68
AKNN	.69	.56	MBTAN	-.08	.69
AKNL	.63	.53	MBTAZ	-.10	.58
AKNT	.68	.51	MESDM	-.27	.74
			MEBML	.60	.74
			ME20V	.64	.74
			MSVIS	-.56	.33
			MSHIL	.74	.35
			MSIZP	-.38	.28
			MRDTS	-.21	.44
			MRSNK	.74	.35
			MRPLČ	.74	.02
Rd	60,09				27,13

Legend. Rc – canonical correlation coefficient; Rc^2 – coefficient of determination; χ^2 – Bartlett's chi square test; *p* – statistical significance level of canonical function; *Rd* – redundancy coefficient

Using the multivariate model between the system of predictor morphological variables and criterion variables, two pairs of statistically relevant orthogonal

canonical factors have been extracted. The canonical correlation coefficient, meaning the correlation within the first orthogonal pair of canonical factors, is the highest and is .91, which indicates that there is a high level of interaction between linear combinations, which further suggest that there is reliability of the level of prediction for the two analyzed groups of variables. Coefficient of determination or squared structure coefficients points to the maximum proportion of mutual variability (91%) which manifest variables share with this pair of canonical function. The remaining 19% for explaining total variance of motor skills can be attributed to other characteristics and skills of the participant (cognitive, conative, functional, etc.) which have not been part of this research, as well as to the test conditions. The results of the Bartlett's test for the first pair of canonical factors revealed the statistical significance of canonical correlations on the level of 1%.

With the lower value of canonical correlation coefficient and 33% of the explained mutual variance, the second isolated independent canonical factor, the level of error in conclusions being 5%, indicates that there is moderate level of linear correlation of this dimension between the two sets of variables.

Having the insight into the matrix of the structure of canonical factors, it can be seen that the biggest influence on the formation of the equation for the unipolar canonical factor, within morphological domain, have standardized canonical coefficients of the following independent variables: body mass (r = .90), body height (r = .87) and forearm circumference (r = .85). On the other hand, the structure of the first canonical dimension in the motoric domain is maximally loaded with criterion projections of the variables horizontal reverse plank (r = .76), knee push-ups (r = .74) and stick mobility (r = .69). Based on the individual contribution, these are the relatively most important variables which determine the results on the canonical function, which indicates that this canonical dimension (CAN_1) of boys where mesomorph type of constitution is dominant is extracted using maximum information between the two analyzed parts, so it is interpreted (on the hypothetical level) as an *integrated morphological factor and the factor of static and repetitive strength and coordination*.

The matrix of the structure of canonical factors of the second canonical function within the morphological domain is predominantly determined by the saturation of the predictor variables subcutaneous fat and elbow diameter, or to say body height, leg length and arm length. On the other hand, the second canonical factor within the domain of the dependent motor variables is mostly defined by the positive saturation of independent variables 20 m sprint with standing start (r = .74), standing long jump (r = .70), hand tapping (r = .68) and foot tapping (r = .66). Based on the individual contribution, these are the relatively most important variables in forming the results on the canonical function which indicates that this canonical factor (CAN_2) of boys with endomorph type of constitution, with 1/3 of the mutual variability, can theoretically be

interpreted as *integrated morphological factor and the factor of explosive strength and flexibility*.

The calculated indicators of redundancy estimate, which are the proportions of variability of one canonicals group of variables that can be explained based on the other group of variables, shows that the applied system of variables of morphological characteristics estimates 60,09% of the variability of the set of the motor skills variables, while the system of the motor skills variables that was used has lower level prediction of the system of anthropometric variables (27,13%).

To conclude, based on the calculated canonical correlation coefficient and the coefficient of determination it is possible to accept the hypothesis proposed in this research – "that there is statistically significant linear correlation between morphological characteristics and motor skills on the sample of 12-year-old preadolescent".

DISCUSSION

With the aim of examining the linear correlation between the groups of variables of morphological characteristics (predictors) and variables of motor skills (criterion) among preadolescent students, canonical correlation analysis was used (Jendoubi *&* Strimmer, 2018)[18].

The relations set of the first pair of linear canonical functions, with the high percentage of the explained variance, revealed that preadolescents who have higher values of canonical weight in anthropometric measurements of body mass, body height and forearm circumference achieve better results on motor skills tests for horizontal reverse plank, knee push-ups and stick mobility. The obtained results show that the extracted physiological-functional and biochemical structure is the dominant generator of canonical coefficients within the structure of canonical dimension of morpho-motoric factor. So, the students who have relatively longer bones and body mass will probably be more successful in conducting the composite motor manifestations of static and repetitive strength and coordination. In conclusion, such isolated canonical pair of linear functions between the groups of manifested variables of morphological characteristics and motor skills, with mutual variability of 91%, is defined as an integrated morphological factor and the factor of static and repetitive strength and coordination. The canonical correlation of the second pair of linear canonical functions indicates that the participants who have higher values of subcutaneous fat, elbow diameter and longitudinal dimensionality of the skeleton, achieve better

[18] Takoua Jendoubi и Korbinian Strimmer, „A whitening approach to probabilistic canonical correlation analysis for omics data integration*", BMC Bioinformatics, 20*(1), (2018): 15– 26.

results on motor skills tests of 20m sprint with standing start, standing long jump, hand tapping and foot tapping. Therefore, this isolated second canonical factor, with endomorph type of constitution, and with statistically significant mutual variability, is interpreted as integrated morphological factor and the factor of explosive strength and flexibility.

The results obtained in this research are similar to the ones found in the empirical studies of other authors (Bajrić et al., 2011[19]; Branković, 2011[20]; Đelaš, 2005[21]; Đorđević et al., 2014[22]; Ivanović & Ivanović, 2017[23]; Jerković, 2011[24]; Jozić, 2002[25]; Malacko & Popović, 2005[26]; Malacko & Rađo, 2007[27]; Pejčić et al., 1987[28]; Pejčić & Malacko, 1992[29]; Markutović, 2018[30]; Matić, 2006[31]; Vlahović & Babin, 2018[32]).

[19] Osmo Bajrić i dr., „Kanonička povezanost morfoloških karakteristika i motoričkih sposobnosti kod učenika“, *Sportske nauke i zdravlje, 1*(2), (2011): 129–134.

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[22] Marija Đorđević i dr., „The correlation between anthropometric characteristics and motor abilities in seven year old girls“, *Facta Universitatis, Series: Physical Education,12*(3), 2014: 251– 260.

[23] Miroljub Ivanović i Uglješa Ivanović, „Relacije antropometrijskih parametara i motoričkih umeća učenica u predadolescentnom periodu”, *Glasnik Antropološkog društva Srbije, 52*, (2017): 17–28.

[24] Zlatko Jerković, „Relacije morfoloških karakteristika i motoričkih sposobnosti učenika sedmog i osmog razreda osnovne škole“ (magistarski rad, Kineziološki fakultet, Split, 2011).

[25] Marijan Jozić, „Relacije između morfoloških karakteristika i motoričkih sposobnosti učenika 5. i 6. razreda”. (*Zbornik radova 11. Ljetne škole kineziologa Republike Hrvatske,* Rovinj: Sveučilište u Splitu, 144-149, 2002).

[26] Julijan Malacko i Dragan Popović, „Relacije između sistema morfoloških i motoričkofunkcionalnih varijabli i njihov uticaj na aerobni kapacitet kod dece 5. razreda osnovne škole”, *Homosporticus 8*(2), (2005): 6–10.

[27] Julijan Malacko i Izet Rađo, „Relacija između fleksibilnost, morfoloških karakteristika i motoričkih sposobnosti kod dečaka uzrasta od 11-12 godina” (Zbornik naučnih i stručnih radova: Nove tehnologije u sportu, Sarajevo: Fakultet sporta i tjelesnog odgoja Univerziteta u Sarajevu, 279-283, 2007).

[28] Aleksandra Pejčić i dr., „Kanoničke relacije morfoloških karakteristika i motoričkih sposobnosti u jedanaestogodišnjih dječaka” (*Zbornik radova III. Kongres pedagoga fizičke kulture Jugoslavije*. Novi Sad, Fakultet fizičke kulture, 119, 1987).

[29] Aleksandra Pejčić i Julijan Malacko, „Kanoničke relacije između morfoloških karakteristika i motoričkih sposobnosti kod dječaka od jedanaest godina“, *Fizička kultura, 23*(2), (1992): 39–45.

[30]

[31] Radenko Matić, „Relacije motoričkih sposobnosti, morfoloških i socioekonomskih karakteristika dece mlađeg školskog uzrasta“ *(*magistarska teza, Novi Sad: Fakultet sporta i fizičkog vaspitanja, 2008).

[32] Lidija Vlahović i Bojan Babin, Analiza povezanosti morfoloških karakteristika i motoričkih znanja kod jedanaestogodišnjih učenika. *Školski vjesnik, 67*(2), (2018): 227–238.

Based on the findings of this research, one can see which anthropometric characteristics give the most information for realization of motor manifestations. In addition, the obtained results give insight into the current state of morpho-motoric structure of students and into the transformational values of certain kinesiological operators, i.e. curriculum, and all that enables the rational and successful realization of physical exercises and physical education classes. Besides that, the results obtained in this cross-sectional study give insight into the make-up of the relations of morphological characteristics and motor skills, with particular emphasis on defining the direction and the size of the contribution of certain anthropometric characteristics to certain motor skills tasks. That is why these empirical findings are, as the basis of understanding model specifications of certain motoric structures, directly applicable to the area of physical education in schools, and are therefore relevant factor in diagnosing anthropological skills, optimal planning, and realizing, controlling and distributing curriculum, as well as for individual orientation and selection of preadolescents for maximum competitive range in some athletic activities.

The greatest advantage of this study is that all the morpho-motoric indicators are measured directly, with relatively small statistical error. However, the main shortcoming of this study is its relatively small sample and limited geographical location, and therefore generalization of results is a relatively big problem.

Theoretical significance of this research can be seen through entire overview and systematization of the relevant literature, as well as through the contribution to development of the general theory of anthropological status and correlations between morpho-motoric potentials among preadolescents. The extracted canonical linear functions identified the mechanisms of relevant sub-segments of anthropological status (morphological and motoric) which are responsible for the more efficient realization of the curriculum. Besides, the obtained findings postulate high level of reliability, which was found using the model of canonical correlation analysis. At the same time, they reveal the current state of morphological characteristics and motor skills of students who are in the stages of early adolescence. Practical application of these findings can be seen in the formation of optimal anthropological model of students age 11 to 12, or more precisely it gives the answer to how efficient a student can be based on his or hers anthropometric and motoric potential. In addition, the obtained findings enable the comparison with the results from the researches conducted in the republic of Serbia and some results from the region and Europe.

Future research of longitudinal and experimental type should include the broader sample of participants of various ages and from various cities in Serbia, construct the new battery of composite measuring instruments of the model for the selection of morphological and motor variables, and then check the findings of the studies that used other mathematical and statistical models of data processing such as the use of multiple regression analysis.

CONCLUSION

In this transversal study the relations between predictors (anthropometric characteristics) and criterion (motor skills) of fifth grade elementary school students from Valjevo were analyzed. The correlation analysis, with the error probability of 5%, revealed the statistically significant interactions of low and moderate intensity between the examined morphological (16) and motor variables (21).

By applying the canonical correlation analysis of the variables in two multidimensional systems of manifested morphological markings and motoric variables, with 91% of the explained variance, bicomponent structure with two pairs of statistically significant canonical factors with relatively high linear connections was extracted. The construct of the relations of the first pair of linear function showed the 12-year-old students who have bigger body mass, body height and forearm circumference achieve better results on motor skills tests for horizontal reverse plank, knee push-ups and stick mobility. The latent basis of this heterogeneous condensated structure is hypothetically interpreted as integrated *morphological factor and the factor of static and repetitive strength and coordination*. The canonical correlation of the second pair of linear function show that the boys who have higher values of subcutaneous fat, elbow diameter and longitudinal dimensionality of the skeleton, achieve significantly better results on motor skills tests of 20m sprint with standing start, standing long jump, hand tapping and foot tapping. The isolated structure of the second canonical pair is theoretically defined as integrated morphological factor and the factor of explosive strength and flexibility.

The obtained results revealed the relevance of identifying the influence of anthropometric characteristics on motor manifestations of preadolescents. These results are the starting point of the more efficient analysis of the relations between the examined variables, which will enable the higher level of understanding morpho-motoric functions among preadolescents. Due to the lack of other researches on this subject and similar researches conducted on preadolescent population in the republic of Serbia, this study is a contribution to predicting the correlation in the morpho-motoric domain, which implies the need for bigger focus on it during physical education of students who are in the stages of puberty.

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КАНОНИЧКЕ РЕЛАЦИЈЕ ИЗМЕЂУ АНТРОПОМЕТРИЈСКИХ И МОТОРИЧКИХ ДИМЕНЗИЈА КОД 12-ГОДИШЊИХ УЧЕНИКА

САЖЕТАК

Циљ овог емпиријског истраживања био је испитивање корелација између скупова варијабли антропометријских карактеристика (16) и моторичких способности (21) од 154 ученика (AS = 11,53 SD = 1,12). Повезаност парова линеарних функција предикторских и критеријумских варијабли процењивана је методом канонички корелационе анализе. Добијени канонички коефицијенти и канонички оптерећења показали су, на нивоу значајности ($p \leq 0,05$ или $p \leq 0,01$), висок ниво повезаности линеарних комбинација испитиваних морфолошких обележја и моторичких способности, уз количину објашњене заједничке варијансе од 80% и 33% за прву, односно другу канонички функцију. Екстраховани релевантни канонички парови хипотетички интерпретирани су као „Интегрисани морфолошки фактор и фактор статичке и репетитивне снаге и кординације", а други „Морфолошки фактор и фактор експлозивне снаге". Склоп првог каноничког морфолошког фактора и фактора статичке и репетитивне снаге, и кординације максимално оптерећују варијабле мере телесне масе, висине тела, обима подлактице, хоризонталног издржаја на леђима, склекова на коленима и окретност с палицом, док највећи допринос структури другог каноничког морфолошког фактора и фактора експлозивне снаге и флексибилности дају варијабле спринт на 20 м из високог старта, скок удаљ из места, тапинг руком и тапинг ногом. Нађени резултати анализираног каноничког двокомпонентног модела упућују у потпуније дефинисање и предикцију структуре корелација антропометријских карактеристика и моторичких манифестација, те дају смернице у планирању, програмирању и контроли тренажних оператора у школском физичком васпитању.

Кључне речи: ученици, морфолошке варијабле, моторичке манифестације, канонички фактори

КАНОНИЧЕСКИЕ ОТНОШЕНИЯ МЕЖДУ АНТРОПОМЕТРИЧЕСКИМИ И ДВИГАТЕЛЬНЫМИ ИЗМЕРЕНИЯМИ У 12-ЛЕТНИХ ШКОЛЬНИКОВ

АННОТАЦИЯ

Цель данного эмпирического исследования – изучение корреляций между группами переменных антропометрических характеристик (16) и двигательных навыков (21) у 154 студентов (AM = 11,53 SD = 1,12). Для оценки корреляции между парами линейных функций предикторных и критериальных переменных использовался метод канонического корреляционного анализа. Полученные канонические коэффициенты и канонические веса показали, что при уровне значимости ($p \leq 0{,}0{,}5$ или $p \leq 0{,}01$) наблюдается высокий уровень корреляции между линейными комбинациями исследуемых морфологических характеристик и двигательными навыками, где объясненная взаимная дисперсия составила 80% для первой и 33% для второй канонической функции. Извлеченные соответствующие канонические пары были гипотетически интерпретированы следующим образом: первая как "интегрированный морфологический фактор и фактор статической и повторяющейся силы и координации", а вторая была интерпретирована как "морфологический фактор и фактор взрывной силы". Совокупность первого канонического морфологического фактора и фактора статической и повторяющейся силы, а также координации, является максимальным весом по переменным – масса тела, рост тела, окружность предплечья, горизонтальная обратная планка, отжимание от колена и подвижность палки, в то время как наибольший вклад в структуру второго канонического морфологического фактора и фактора статической и повторяющейся силы имеют переменные – 20-метровый спринт со стартом из позиции стоя, прыжок в длину стоя, сгибание руки и сгибание ноги. Полученные результаты анализируемой двухкомпонентной канонической модели раскрывают более определенную и предсказуемую структуру корреляции между антропометрическими характеристиками и двигательными проявлениями, следовательно, предлагаются рекомендации по планированию, разработке и контролю тренировочных процессов на занятиях физической культурой.

Ключевые слова: студенты, морфологические переменные, двигательные проявления, канонические факторы.

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