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Original empirical article

THE CORRELATION BETWEEN ANTHROPOMETRIC, MOTOR AND THE VARIABLES FOR THE EVALUATION OF BONE DENSITY

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Abstract. *Even though the precise mechanisms of the influence of physical activity on the formation of tissue have not been described in great detail, it is known that physical activity plays an important role in this process. It has already been determined that many children develop and improve their motor skills during their daily activities, since it is at these times that they perform basic movements such as running, jumping, climbing and turning. Aims: The aim of this research was to determine if there is any relation between anthropometric characteristics, motor skills or bone density of the participants. Material and Methods: The data for the current research was gathered as part of the scientific project "The integral development, physical activity and aberrant behavior of preschool children" financed by the Ministry of Science and Technological Development of the Republic of Serbia. All of the participants were children (a total of 184 i.e., 115 boys and 69 girls) attending preschool on the territory of the city of Novi Sad, and they were all aged 3.5 to 7. The measurements for the evaluation of anthropometric characteristics included the following: body height, body weight, and upper arm skinfolds. The evaluation of the motor skills was carried out using the following motor tests: 1) the 20 meter run; 2) the polygon backwards; 3) hand tapping; 4) hyperextensions in a seated position, legs apart; 5) the standing depth jump; 6) hanging pull-ups and 7) torso lifts during 60 s. Bone density was determined with the help of a sonometer Sahara Hologic, Inc., MA, USA. The following measurements of the bone density were made: 1) the decrease in the strength of the sound signal– the left leg (Broadband Ultrasound Attenuation, BUALL in dB/MHz); 2) the decrease in the strength of the sound signal - the*

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right leg (BUARL in dB/MHz). The analyses of the differences in terms of the gender of the participants and in regard to the applied variables of anthropometric characteristics, motor skills and bone density included a multivariate and univariate analysis of variance, while the relations between the variables were evaluated by means of Pearson's correlation and the regression analysis. Results: Based on the results of the multiple correlation coefficient (R) and the remaining parameters (the F-test and statistical significance P), it can be concluded that there is a correlation between the predictor system of variables, anthropometrics and motor skills and the criterion, the variables for the evaluation of bone density, both in boys and girls. By analyzing the regression coefficients, we noted the individual influences of the variables of the predictor system on the criterion variables. Conclusion: The results of this research indicate that there is a clearly pronounced sexual dimorphism in all of the studied spaces – anthropometrics, motor skills and bone density, as well as that a positive influence of certain motor skills, or anthropometric variables on the bone mineral content of the participants can be noted.

Key words: *anthropometric characteristics, motor abilities, bone density, children, correlation.*

INTRODUCTION

Even though the precise mechanisms of the influence of physical activity on the formation of tissue have not been described in great detail, it is known that physical activity plays an important role in this process (Bubanj, S. & Obradović, 2002). Significant stimuli can also occur due to moderate intensity physical activity which is the result of our everyday activities. Thus, the anabolic influence of physical activity is not limited solely to athletes who train and thus increase their muscle strength and endurance. This has led to a widely accepted conclusion that physical activity improves the process of bone formation, and thus affects bone density as well (Eliakim & Beyth, 2003). It has already been determined that many children develop and improve their motor skills during their daily activities, since it is at these times that they perform basic movements such as running, jumping, climbing and turning (Saakslahti et al., 1999). For the development of motor characteristics such as strength or endurance, special movement abilities are needed. Irrespective of the level of an individual's motor skills, physical activity aimed at improving one's overall health status is appropriate for everyone. The potential contribution of physical activity to the increase in bone mass is very important in the case of children and adolescents, since bone density reaches approximately 90% of its maximum value towards the end of the second decade of one's life (Glastre et al., 1990). This supports the fact that different forms of physical activity during childhood and adolescence can prevent bone disorders (such as osteoporosis) during one's lifetime. Most of the cross-sectional research that has been carried out on healthy children and adolescents indicates that a higher level of physical activity is actually related to increased bone mass (Ruiz et al., 1995; Recker et al., 1992; Slemenda et al., 1991). In addition, achieving higher bone mass during childhood and adolescence represents a key factor for a healthy skeletal system. The latest research indicates that children with reduced motor abilities are less physically active and thus are more prone to obesity (Tsiotra et al., 2006; Cairney et al., 2005), cardiovascular disorders (Faught et al., 2005) and impaired physical abilities, especially functional abilities, muscle strength and endurance, agility (Hands & Larkin, 2006) and body composition (Schott et al., 2007; Hands & Larkin, 2006). Hands & Larkin (2002) indicated that inadequate physical activity can be accounted for by ineffective motor control, or in other words, mechanical ineffectiveness. If the aforementioned components of physical activity are not accessible to people with reduced motor skills, then 5-10% of the population does not have the ability to prevent chronic disorders. In addition, these people cannot even benefit from the positive influence of physical activity during their lifetime (Pate et al., 1996). Nevertheless, children today spend less time participating in certain types of physical activity or sport, and devote most of their time to watching television or playing video games (Andersen et al., 1998). This sedentary lifestyle creates preconditions for obesity and can lead to a decrease in bone mass. The aim of this research was to determine whether any relations between anthropometric characteristics, motor skills or bone density can be found.

MATERIAL AND METHODS

The data for the current research was gathered as part of the scientific project "The integral development, physical activity and aberrant behavior of preschool children" financed by the Ministry of Science and Technological Development of the Republic of Serbia. With the purpose of determining the relations between anthropometric characteristics, motor skills and bone density, a total of 184 participants were examined during the course of this study. All of the participants were children attending preschool on the territory of the city of Novi Sad, and they were all aged from 3.5 to 7. The sample of participants included 115 boys and 69 girls. None of the participants had any medical conditions or illnesses that could have a secondary influence on bone metabolism. The measurements for the evaluation of anthropometric characteristics included the following: body height, body weight, and upper arm skinfolds. According to Božić-Krstić et al. (2005), the cited anthropometric features are considered the basic measurements on the basis of which we can evaluate the growth and development of children. An overview of recent research (Katić et al., 1994; Bala, 1981) indicates that these measurements, in the case of children, cover a two-dimensional model of morphological dimensions: the dimensionality of the skeleton and voluminosity and subcutaneous fatty tissue. The manner and conditions under which the measuring took place were in accordance with the recommendations of the International Biological Program - IBP (Lohman et al., 1988). The evaluation of the motor skills was carried out using the following motor tests: 1) the 20 meter run; 2) the polygon backwards; 3) hand tapping; 4) hyperextensions in a seated position, legs apart; 5) the standing depth jump; 6) hanging pull-ups and 7) torso lifts during 60 s. These tests are considered the best manifestations of the hypothetical latent model of motor skills in the case of adults (Kurelić et al., 1975), while when dealing with children, it is usually the case of the general motor factor (Bala et al., 2009; Bala, 1981) or the two-dimensional model, where the first factor is as the general factor of motor skills, while the second factor is the factor of agility (Bala et al., 2009; Bala & Popović, 2007). The motor testing was carried out following the standardization of the motor tests in accordance to the recommendations given by Bala et al. (2007). Each child underwent a trial testing prior to the recording of their final results. What follows is a short description of the cited motor tests:

1. *The 20 m run*. Following the command "go", the children start to run as fast as they can from the start line until the end of the track (20 meters). The participants run in pairs, and their time is measured in tenths of a second.

2. *The polygon backwards*. The child walks backwards by touching the ground with both legs and both arms during the walk and stays on course by looking between its legs. The task is completed when the participant covers a distance of 10 meters in this manner, walking across a vault box and passing through its frame. The results of this motor test were measured with an accuracy of 0,1 s.

3. *Hand tapping*. The task requires the participant to, while sitting on a chair for 15 seconds, touch two squares placed on a table as many times possible with the fingers of his dominant hand, while his non-dominant hand is placed between the two squares on the table. The legs of the child should be on the floor during the entire task, and the overall number of touches of both sides of the square is recorded.

4. *Hyperextensions in a seated position, legs apart*. The participant sits on the floor, with his back to the wall. His outstretched legs he places along the lines marked on the floor at an angle of 45°. After that, the participant places his arms in such a way so that his upper arms are one above the other and touches the floor with his hands. This represents the zero mark on the measuring tape. From this position the participant performs hyperextensions to the best of his ability. The results in this test are marked as the value which the examiner records (in cm), and which the participant touches on the measuring tape, while maintaining the full extent of the hyperextension.

5. *The standing depth jump*. The initial position for the performance of this motor task requires that the participant places his feet on the edge of a reverse positioned Reuter jump board, which was placed on the track, and on which various values were marked in cm. The result of the test was the length of the jump (in cm).

6. *Hanging pull-ups*. The child, with the help of the examiner, raises itself to the position of the hanging pull-up with his hand in an underhand grip (at shoulder width), and with his chin above the bar. This task requires that the participant hold the initial position as long as possible, and the result is expressed in seconds with an accuracy of 0,1 s.

7. *Torso lifts during 60 s.* The participant lies in a supine position with his arms crossed over his chest. Following the command “now“, he sits up as quickly as possible, so that he touches his thighs with his elbows, and then returns to his original position. The examiner holds his feet and lower legs during the performance of the task. The result of this test is measured by the number of times a participant correctly lifts and lowers his body for a period no longer than 60 seconds.

Bone density was determined with the help of a sonometer with the non-ionizing ultrasound *Sahara Hologic, Inc*., *MA, USA*. During the evaluation of the bone density of the participants, the following measurements were made: 1) the decrease in the strength of the sound signal– the left leg (*Broadband Ultrasound Attenuation*, BUALL in dB/MHz); 2) the decrease in the strength of the sound signal– the right leg (BUARL in dB/MHz). The analyses of the differences in terms of the gender of the participants and in regard to the applied variables of anthropometric characteristics, motor skills and bone density included a multivariate and univariate analysis of variance, while the relations between the variables were evaluated by means of Pearson’s correlation and the regression analysis (Pallant, 2007).

RESULTS WITH DISCUSSION

In table 1 we can find the basic descriptive statistical variables, as well as the differences in terms of gender, which were studied by means of the analysis of variance, while in table 2 we can find the intercorrelations of the anthropometric variables, motor variables and the variables for the evaluation of bone density.

Table 1. The basic descriptive statistical variables and differences based on gender.

Variables	Boys N=115		Girls N=69		f	p
	AS	S	AS	S		
Anthropometric variables						
Body height (mm)	1165,25	68,50	1154,62	78,32	0,93	0,33
Body weight (0,1 kg)	220,31	46,48	219,03	48,58	0,03	0,85
Upper arm skinfolds (mm)#	86,39	31,27	96,90	29,77	5,04	0,02
Motor variables						
The 20m run (0,1 s) #	55,78	7,07	57,72	7,91	2,96	0,08
The polygon backwards (0,1 s) #	261,51	86,01	323,58	121,00	16,44	0,00
Hand tapping (freq.)	14,98	3,58	14,07	2,99	3,13	0,07
Seated hyperextensions (cm)	33,57	6,34	36,88	7,41	10,39	0,00
The standing depth jump (cm)	109,23	21,79	99,55	22,76	8,23	0,00
Hanging pull-ups (0,1 s)	124,30	112,87	93,07	81,48	4,02	0,04
Torso lifts (freq.)	15,29	9,80	13,81	8,43	1,08	0,30
Variables for the evaluation of bone density						
BMD (left leg)	0,49	0,07	0,52	0,09	6,52	0,01
BMD (right leg)	0,51	0,08	0,54	0,08	3,99	0,04
		F=4,93	P=0,00			

Legend: AS – arithmetic means; S – standard deviation; f – the univariate f-test; p – the statistical significance of the univariate f-test; F – the multivariate F-test; P – the statistical significance of the multivariate F-test; # – the variable with inverse metrics

Based on the data presented in table 1, we can conclude that differences in terms of gender exist in all the studied spaces (anthropometrics, motor skills, bone density). For that reason, in the remainder of the article, the sample of participants will be treated separately and the relations between the variables will be studied for both sexes. By analyzing the results in table 2 for both the group of males and females, a positive statistically significant correlation was determined between bone density and the motor test “the polygon backwards“, with a statistical significance at the $p<0,05$ level.

Table 2. The intercorrelation matrix of the anthropometric variables, motor variables and the variables for the evaluation of bone density (boys – lower triangle, girls – upper triangle).

Variables	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1. Body height		,82[b]	,36[b]	-,36[b]	-,21[a]	,14	,29[b]	,29[b]	,08	,30[b]	,09	,22
2. Body weight	,76[b]		,70[b]	-,14	-,03	,01	,24[a]	,02	-,19	,04	-,05	,03
3. Forearm skinfold[#]	,23[b]	,37[b]		,13	,32[b]	-,11	,10	-,27[b]	-,42[b]	-,16	-,20	-,22
4. The 20m run[#]	-,51[b]	-,20[a]	,12		,64[b]	-,67[b]	-,25[a]	-,68[b]	-,38[b]	-,47[b]	-,24[a]	-,10
5. The polygon backwards[#]	-,34[b]	-,01	,15	,74[b]		-,56[b]	-,21[a]	-,70[b]	-,47[b]	-,48[b]	-,26[a]	-,25[a]
6. Hand tapping	,28[b]	,14	,04	-,52[b]	-,49[b]		,19	,59[b]	,32[b]	,38[b]	,06	-,04
7. Hyperextensions, seated position	,47[b]	,36[b]	,07	-,33[b]	-,25[b]	,27[b]		,20	,03	,03	,11	,20
8. Standing depth jump	,45[b]	,19[a]	-,15	-,76[b]	-,67[b]	,57[b]	,34[b]		,58[b]	,45[b]	,19	,27[a]
9. Hanging pull-ups	,12	-,01	-,23[b]	-,36[b]	-,36[b]	,32[b]	,15	,40[b]		,43[b]	,10	,14
10. Torso lifts	,30[b]	,16[a]	-,06	-,56[b]	-,52[b]	,48[b]	,21[a]	,53[b]	,42[b]		,23[a]	,28[a]
11. BMD (left leg)	,09	,03	-,23[a]	-,17	-,21[a]	,02	,09	,15	,15	-,03		,68[b]
12. BMD (right leg)	-,03	-,09	-,19[a]	-,03	-,05	-,14	-,20[a]	,00	,05	-,03	,51[b]	

Legend: [a] – statistical significance ≤ 0,01; [b] – statistical significance ≤ 0,05; [#] – a variable with inverse metrics

In the case of the boys, a positive correlation was determined between the upper arm skinfold and the "hyperextensions in a seated position" motor test and the bone density of both legs, while in the case of the girls, a positive correlation was noted between bone density and the variables for the evaluation of repetitive and explosive strength. Statistically significant relations with a negative value between the upper arm skinfold and the "polygon backwards" and bone density can, due to the inverse metrics, be considered qualitative positive relations, since lower level results for these variables actually represents better results. The determined statistically significant correlations represent the basis for the regression analysis shown in table 3. Based on the results of the multiple correlation coefficient (R) and the remaining parameters (the F-test and statistical significance P), it can be concluded that there is a correlation between the predictor system of variables, anthropometrics and motor skills and the criterion, the variables for the evaluation of bone density. A correlation was also determined in the case of the boys and the girls, but in a somewhat altered form. Namely, along with a statistical significance of (P=0,026) a correlation was determined between the given predictor system and the variables which were used to evaluate bone density, based on the analysis the left heel bone. In addition, the same was determined in the case of the girls, with a statistical significance of (P=0,007), only in this case the correlation was noted in regard to the right heel bone. The correlations in both cases are mathematically and logically positive. By analyzing the regression coefficients, we noted the individual influences of the variables of the predictor system on the criterion variables. The statistically significant influence in the case of the boys was also noted in the following variables: torso lifts (p=0,013), upper arm skinfolds (p=0,019) and the polygon backwards (p=0,045). A further interpretation of the regression coefficient can lead us to note that, mathematically speaking, all the relations are negative, which means that an increase in the values in the variables of the predictor system, leads to a decrease in the values of the criterion variable.

Table 3. The regression coefficient and the multiple correlation coefficient of the anthropometric and motor variables for the evaluation of bone density.

Variables	Boys				Girls			
	BMD (left leg)		BMD (right leg)		BMD (left leg)		BMD (right leg)	
	β	p	B	p	β	p	β	p
Body height	0,009	0,958	0,193	0,280	0,307	0,165	0,345	0,250
Body weight	0,186	0,237	-0,068	0,675	-0,380	0,354	-0,154	0,667
Upper arm skinfold#	-0,249	0,019	-0,156	0,150	-0,049	0,338	-0,246	0,239
The 20 m run#	-0,027	0,868	-0,068	0,684	-0,211	0,833	0,194	0,289
The polygon backwards#	-0,284	0,045	-0,093	0,518	-0,193	0,298	-0,114	0,526
Hand tapping	-0,071	0,564	-0,208	0,104	-0,263	0,331	-0,348	0,033
Seated hyperextensions	0,043	0,680	-0,255	0,020	0,085	0,141	0,144	0,228
The standing depth jump	0,050	0,748	-0,016	0,919	-0,007	0,518	0,352	0,070
Hanging pull-ups	0,116	0,274	0,070	0,520	-0,152	0,974	-0,246	0,114
Torso lifts	-0,310	0,013	-0,011	0,930	0,144	0,376	0,301	0,044
F	2,155		1,469		1,216		2,801	
P	0,026		0,161		0,301		0,007	
R	0,414		0,352		0,416		0,571	

Legend: β – regression coefficient; p – the statistical significance of the regression coefficient; F – F-test; P – the statistical significance of the F-test; R – the multiple correlation coefficient; # – the variable with inverse metrics

This increase has logically been confirmed only in the case of the torso lifts variable, since in the case of the upper arm skinfold and the polygon backwards variable, in which inverse metrics were detected, an increase in one leads to a quantitative decrease in the other, but also to a qualitative, logical increase. The influence on the second, criterion variable, the evaluation of bone density in the right heel bone, was determined only in the case of the hyperextensions in a seated position variable. This influence is statistically significant only at the (P=0,020) level, with a mathematical and logically negative value of the regression coefficient. The higher values achieved for the hyperextensions in a seated position variable caused poorer results for the variable for the evaluation of bone density. In the case of the girls, the influence of the predictor variables was determined only in the case of the criterion variable which was used to evaluate the bone density of the right heel bone. It was determined that the hand tapping variable causes statistically significant lower values of the criterion variable, while the torso lifts during 60 s variable led to a statistically significant increase in the value of the criterion. The physical activity of children cannot satisfactorily be quantified using the self-evaluation method, since children do not have the cognitive abilities to remember the patterns and details of their activities, while it is precisely physical activity in combination with other factors that has a positive effect on their skeletal system (Rowlands et al., 1997). Nevertheless, Janz et al. (2008) studying a sample which included 449 children, with an average age of 11, and using a questionnaire for the self-evaluation of the physical activities of children (PAQ-C), noted a correlation between body height, body weight and maturity and the bone mineral content (BMC). In addition, they determined that the correlation between everyday physical activity and the BMC was more pronounced in the case of girls than in the case of boys. Slemenda et al. (1994) in a longitudinal three-year study which included 90 children, aged 6-14, evaluated the density of the bone tissue and the BMD in the area of the lower arm, spinal column and hip joints by using the DEXA methods, and evaluated physical activity by using a questionnaire. The sexual maturity of the children was determined every six months by an endocrinologist in accordance with the Tanner Development Scale, with the aim of classifying children into prepubescent, pubescent and postpubescent categories. The results showed that an increase in body height was connected to the cortical bone, while the increase in body weight was related to the trabecular bone. Physical activity was related to the increased ossification of the skeletal system among prepubescent children. In addition, the results of a research which included children aged 8 and over, indicate that anthropometric characteristics and physical activity are predictors of the density of bone tissue in the case of children (Laing et al., 2005; Cassel et al., 1996; Kroger et al., 1993).

CONCLUSION

The results of this research indicate that there is a clearly pronounced sexual dimorphism in all of the studied spaces – anthropometrics, motor skills and bone density, as well as that a positive influence of certain motor skills, or anthropometric variables on the bone mineral content of the participants can be noted. Thus, taking part in physical activity during childhood can have a strong positive influence on the health status and bone density of the bone tissue of adults.

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POVEZANOST ANTROPOMETRIJSKIH, MOTORIČKIH I VARIJABLI ZA PROCENU KOŠTANE GUSTINE

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Uvod: Iako još uvek nisu u potpunosti poznati mehanizmi uticaja fizičke aktivnosti na stvaranje tkiva, fizička aktivnost u tome ima važnu ulogu. Kao što je već rečeno, mnoga deca razvijaju i unapređuju motoričke sposobnosti tokom dnevnih aktivnosti, jer tada izvode osnovna kretanja kao što su trčanja, skakanja, penjanja i okretanja. Cilj: Cilj istraživanja bio je da se utvrdi da li postoje relacije između antropometrijskih karakteristika, motoričkih sposobnosti i gustine kosti kod dece predškolskog uzrasta. Materijal i Metode: Podaci aktuelnog istraživanja prikupljeni su u okviru naučno istraživačkog projekta pod nazivom „Integralni razvoj, fizička aktivnost i aberantno ponašanje predškolske dece", finansiranog od strane Ministarstva za nauku i tehnološki razvoj Republike Srbije. U istraživanje je uključeno 184 ispitanika (115 dečaka i 69 devojčica), deca iz predškolskih ustanova sa teritorije Novog Sada, uzrasta od 3,5 do 7 godina. Mere za procenu antropometrijskih karakteristika bile su: telesna visina, telesna težina i kožni nabor nadlakta. Procena motoričkih sposobnosti izvršena je primenom sledećih motoričkih testova: 1) trčanje 20 metara; 2) poligon natraške; 3) taping rukom; 4) pretklon u sedu raznožno; 5) skok udalj iz mesta; 6) izdržaj u zgibu i 7) podizanje trupa za 60 s. Gustina kosti procenjivana je pomoću sonometra koji koristi neojonizujući ultrazvuk Sahara Hologic, Inc., MA, USA, a korišćene su sledeće mere: 1) slabljenje zvučnog signala – leva noga (Broadband Ultrasound Attenuation, BUALN u dB/MHz); 2) slabljenje zvučnog signala – desna noga (BUADN u dB/MHz). Analiza razlika po polu ispitanika u primenjenim varijablama antropometrijskih karakteristika, motoričkih sposobnosti i gustine kosti obuhvatila je multivarijatnu i univarijatnu analizu varijanse, dok su relacije između varijabli ispitivane pomoću Pirson-ove analize korelacija i regresione analize. Rezultati: Bazirajući se na rezultate koeficijenata multiple korelacije (R) i drugih parametara (F-testa i statističke značajnosti P) može se zaključiti da postoji povezanost između prediktorskog sistema varijabli, antropometrije i motorike i kriterija, varijabli za procenu denziteta kosti i kod dečaka i kod devojčica. Posmatrajući regresione koeficijente uočeni su pojedinačni uticaji varijabli prediktorskog sistema na kriterijske varijable. Zaključak: Rezultati ovog istraživanja ukazuju da postoji jasno izražen polni dimorfizam po svim ispitivanim prostorima – antropometrija, motorika i gustina kosti, kao i pozitivan uticaj nekih motoričkih sposobnosti, odnosno antropometrijskih varijabli na procenu koštanog mineralnog sadržaja.

Ključne reči: *antropometrijske karakteristike, motoričke sposobnosti, gustina koštanog tkiva, deca, povezanost.*