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SEXUAL DIMORPHISM IN BODY COMPOSITION OF CHILDREN IN THE NORTH BAČKA REGION

POLNI DIMORFIZAM TELESNE KOMPOZICIJE KOD DECE U SEVERNOBAČKOM REGIONU

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Summary
Introduction. Anthropometric measurements are widely used in the assessment of growth, nutritional status and body composition in children. The objective of the study was to describe growth and body composition of children using simple anthropometric measures. **Material and Methods.** The investigation was performed in 13 primary schools in the territory of North Bačka during 2017 and at the beginning of 2018. A total of 593 schoolchildren aged 6.50 - 10.49 years (in decimals) were included in the study. The following parameters were measured: height, weight, upper arm circumference and triceps skinfold thickness. These measurements were used to calculate the body mass index, total upper arm area, upper-arm muscle area, upper-arm fat area, and the arm fat mass percentage for each individual. **Results.** The study results show that children's growth is almost linear over the first decade of life and the lean body mass increases at similar rates in boys and girls. However, girls show higher percentage of body fat and higher triceps skinfold thickness, while the body mass index is not significantly different. The secular trends in height are slowing down or have already ceased, but the weight generally continues increasing. **Conclusion.** Although sexual differences in anthropological measures are insignificant, the differences in body composition are evident before puberty.
Key words: Growth; Puberty; Body Composition; Child Development; Obesity; Adipose Tissue; Anthropometry; Child; Serbia; Sex Characteristics

Sažetak
Uvod. Antropometrijske mere se često koriste za procenu rasta, stanja uhranjenosti i telesne kompozicije kod dece. Cilj ovog istraživanja bio je da se analiziraju rast i telesna kompozicija kod dece pretpubertetskog uzrasta. **Materijal i metode.** Istraživanje je izvršeno tokom 2017. i početkom 2018. godine u 13 osnovnih škola na teritoriji Severne Bačke, a obuhvatilo je 593 učenika uzrasta od 6,50 do 10,49 decimalnih godina. Izmerene su: visina, masa tela, obim relaksirane nadlaktice i debljina kožnog nabora nad tricepsom. Iz ovih mera za svakog ispitanika izračunati su: indeks telesne mase, ukupna površina nadlaktice, mišićna masa nadlaktice, masna masa nadlaktice i procenat masne mase ruke. **Rezultati.** Tokom prve decenije rast dece je skoro linearan, a nemasna masa tela se povećava sličnim intenzitetom kod pripadnika oba pola. Međutim, devojčice pokazuju veći procenat telesne masti i veću debljinu kožnog nabora na tricepsu, dok se indeks telesne mase ne razlikuje značajno. Sekularni trend u visini se usporava, ali masa tela pokazuje i dalje trend porasta. **Zaključak.** Iako polne razlike u antropološkim merama nisu izražene, razlike u sastavu tela su uočljive pre puberteta.
Ključne reči: rast; pubertet; telesni sastav; razvoj deteta; gojaznost; masno tkivo; antropometrija; dete; Srbija; polne karakteristike

Introduction

The growth and development of children is regulated by a complex interaction between internal (biological) and external factors. Complex interaction of hormonal influences, tissue responsiveness and nutrition affect the growth and development of children, whereas metabolic and genetic signals modulate these responses [1]. Some authors reported that genetic factors, more than environmental, determine anthropometric features and these characteristics are highly heritable components, with heritability range from 40 – 91% [2]. Anthropometric characteristics, such as height and weight, are widely used to estimate the growth and development, as well as the nutritional status of children, but changes in body composition are also essential elements in growth. Prepubertal growth is relatively stable and remains constant throughout childhood, until the onset of puberty. A general rule is that a child grows 10 cm in the first year of life and later, to the beginning of puberty, the increase is mostly uniform and in most children 5 to 7.5 cm per year, while the increase of body weight is about 2 – 3 kg per year [3]. Before adolescent growth spurt, boys and girls differ only by some 2% in height, and later by about 8%, on average. In adults, the difference in body height between men and women is around 13 cm, of which 2 cm are due to prepubertal growth. Because of small gender differences in anthropometric characteristics, the prepubertal period is often re-

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Abbreviations

BMI – body mass index
TUA – total upper-arm area
UMA – upper-arm muscle area
UFA – upper-arm fat area
FM% – fat mass percentage
MUAC – mid-upper arm circumference
SD – standard deviation
DI – dimorphism index
TSFT – triceps skinfold thickness

ferred to as the period of neutral childhood. Gender differences in body size and shape seen in adults are the result of differential growth patterns at later period of adolescence. Even though no sex differences were expressed in height and weight, there is some evidence to support sexual dimorphism in body composition, but the time of life when sex differences in body composition first occur is currently unknown.

A number of studies conducted over the last few decades have reported an increasing trend of overweight and obesity in children and adolescents worldwide [4, 5]. Today, the most frequently used anthropometric indicator for evaluation of the nutritional status is the body mass index (BMI kg/m^2). However, BMI cannot point to the body composition and distribution of fat tissue. Determination of body composition, i.e. fat and fat-free mass, is of considerable interest for gathering accurate data of a person's nutritional status. Fat component of the human body represents the fat mass or percentage of body fat, while the non-fat component is known as the lean body mass. Excess weight does not necessarily imply excess fat, and being underweight is not necessarily associated with protein energy malnutrition. This is particularly the case when the degree of under- or overweight is moderate [6]. When it comes to body composition assessment, anthropometric measurements have a lot of practical advantages, such as being non-invasive and inexpensive [7]. Arm anthropometry is used for evaluation of body composition in both clinical and field researches [8]. Such evaluation of fat and fat-free mass relies on facts that the arm is cylindrical in form and the subcutaneous fat is evenly distributed around a circular core of muscle [9]. There is a direct correlation between some diseases, biochemical changes and nutritional status and the upper arm composition. This is explained by the fact that arm contains muscles and the subcutaneous fat tissue represents an important parameter in detecting undernutrition, particularly in situations when it is impossible to measure the height and weight [10]. Many investigations have shown that upper arm muscle area (UMA) and upper arm fat area (UFA) are very good indices of growth and nutritional status of children and adolescents [11 - 14]. Nutritional status and muscle mass can be determined by calculating UMA, which is determined based only on two anthropometric measurements, mid-upper arm circumference (MUAC) and triceps skinfold thickness (TSFT). In this study, we aimed to describe the growth and nutritional status in prepubertal children in North Bačka region by height, weight and upper arm anthropometry derived from MUAC and TSFT.

Material and Methods

Anthropological examination was carried out in 2017 and at the beginning of 2018, in 13 primary schools in the North Bačka region. A cross-sectional sample of 593 schoolboys and girls (N = 302; N = 291, respectively) aged from 7 to 10 years were measured for height, weight, upper arm circumference and TSFT using standard techniques given by Tanner et al. [15]. Age was calculated as the difference between the date of birth and the date of data collection. Age groups were categorized by the midpoint of an age range. For example, the group of participants aged 7 years included all participants between 6.50 and 7.49 years. The subjects were grouped into four age categories (6.50 – 10.49). A formal consent was obtained from participants and their parents before data collection and participation was on voluntary basis. The research protocol was approved by the Provincial Secretariat for Education, Regulations, Administration and National Minorities – National Communities, Scientific Committee of the Department of Biology and Ecology, University of Novi Sad and primary school regulations.

Anthropometric measurements were taken using standard techniques in standing participants wearing light clothing and without shoes. Height was measured using an anthropometer (± 1 mm; Sieber Hegner Maschinen AG Zürich, Switzerland) with the head positioned in the Frankfurt plane (position in which the lower margins of the orbits, the orbitales, and the upper margins of the ear canals, the poria, all lie in the same horizontal plane), and a portable electronic digital scale was used to measure weight with accuracy of ± 0.1 kg. Mid upper arm circumference was measured with a plastic tape with the right arm hanging relaxed at side, and the measurement was done at the mid-point between the tip of the shoulder and the tip of the elbow (olecranon process and the acromion). The TSFT was measured to the nearest 0.1 mm with a Holtain skinfold caliper, at the midpoint between the elbow and the acromion process of the scapula. Three measurements were taken, and the mean was recorded. The BMI was calculated from the ratio of weight/height^2 (kg/m^2). The subjects were classified into underweight, normal weight, overweight and obese, according to age- and sex specific cut-off points proposed by the International Obesity Task Force (IOTF) [16]. Overweight and obesity were defined as having a BMI above the age- and sex-specific thresholds, respectively (equivalent of BMI > 25 kg/m^2 and the equivalent of BMI > 30 kg/m^2). Nutritional status was also assessed by indirect anthropometric measurements

Table 1. Mean, standard deviation and dimorphism index in body height, body weight, mid-upper arm circumference and triceps skinfold thickness in boys and girls
Tabela 1*. Prosečne vrednosti, standardna devijacija i polni dimorfizam visine tela, mase tela, obima relaksirane nadlaktice i debljine kožnog nabora na tricepsu kod dečaka i devojčica*

Anthropometric characteristics *Antropometrijske karakteristike*	Age *God.*	Boys *Dečaci*			Girls *Devojčice*				
		N *Br.*	Mean *Srednja*	SD *Stand. devij.*	N *Br.*	Mean *Srednja*	SD *Stand. devij.*	p	DI % *Polni dimorfizam %*
Body height (cm)‡ *Visina tela (cm)‡*	7	42	125.62	5.70	41	123.98	4.74	0.157	0.43
	8	91	129.04b	5.65	86	129.97c	5.04	0.255	
	9	91	135.13c	6.03	92	134.02c	6.48	0.232	
	10	78	142.03c	7.24	72	141.61c	6.78	0.719	
Body weight (kg)‡ *Telesna masa (kg)‡*	7	42	28.55	7.95	41	25.76	5.32	0.064	5.25
	8	91	28.96	5.53	86	28.85a	4.85	0.891	
	9	91	32.94b	6.58	92	32.53c	7.70	0.699	
	10	78	40.72c	12.57	72	36.90c	8.89	**0.035**	
Mid-upper arm circumference (cm)‡ *Obim relaksirane nadlaktice (cm)‡*	7	42	18.95	3.32	41	18.41	2.82	0.429	0.35
	8	91	18.76	2.65	86	19.12	2.50	0.357	
	9	91	19.37	2.89	92	19.84	3.11	0.297	
	10	78	21.87c	4.30	72	21.29b	3.24	0.350	
Triceps skinfold thickness (mm)† *Debljina kožnog nabora na tricepsu (mm)†*	7	42	12.10	5.96	41	12.73	4.54	0.065	-9.36
	8	91	12.10	4.32	86	14.26	5.20	**0.003**	
	9	91	12.66	5.14	92	15.12	5.33	**0.001**	
	10	78	16.13c	7.59	72	16.31	5.88	0.369	

Legend: ‡ t – One-Way ANOVA for Independent Samples (LSD Post Hoc); † Mann-Whitney U test and Kruskal Wallis test; a, b, c – statistically significant increase in relation to the previous year: [a] $p < 0.05$, [b] $p < 0.01$, [c] $p < 0.001$; Bold values are statistically significant
Legenda: *‡ t – jednosmerna ANOVA za nezavisne uzorke (LSD Post Hoc); † Man-Vitnijev U test i Kruskal Valisov test; a, b, c – statistički značajno povećanje u odnosu na prethodnu godinu: a p < 0,05, b p < 0,01, c p < 0,001; Boldovane vrednosti su statistički značajne*

– total upper-arm area (TUA), UMA, UFA and arm fat mass percentage (FM %). Substituting C for MUAC, and measurements made in centimeters, the following formulas according to Fricancho [6]) were used:

$TUA = C^2/(4 \times \pi) = cm^2$

$UMA = [C – (TSF \times \pi)]^2/(4 \times \pi) = cm^2$

$UFA = TUA – UMA = cm^2$

$FM\% = (UFA \times 100)/UFA + UMA$

The dimorphism index (DI) was calculated based on the equation by Borgognini et al., [17], based on sample means:

$DI = ((Mean_m – Mean_f)/Mean_f)) *100$

where $Mean_m$ stands for males and $Mean_f$ for females.

Data were analyzed with SPSS software for Windows, version 20 (Incorporation, Chicago, USA). Height, weight, MUAC, TSFT, BMI, TUA, UMA, UFA and FM% were expressed as mean ± standard deviation (SD). The Mann-Whitney U test and Independent Sample t-test were used to identify the statistical difference of anthropometric indicators in boys and girls, depending on the normality of the distribution determined by the Shapiro-Wilks test. The difference between the number of boys and girls was determined using the Chi-square test. The age difference was determined using One-Way ANOVA for Independent Samples (LSD Post Hoc) or Kruskal-Wallis test. The overall significance level was set at $p < 0.05$.

Results

There were no statistically significant differences between the mean values of body height and body weight in boys and girls (**Table 1**). Although boys showed slightly higher values of these characteristics, no statistical differences were detected, except for the weight values recorded at the age of ten. The mean DI of height was somewhat lower (0.43%) in comparison with the weight DI (5.25%). The MUAC did not differ significantly (DI = 0.35%), but the mean TSFT was greater in girls of all ages, with significant differences recorded at the ages of eight ($p < 0.001$) and nine ($p < 0.001$). Triceps skinfold thickness values were, on the whole, by 9.36% greater in girls than in boys.

With regard to the BMI (**Table 2**), no significant differences were found between boys and girls. The boys showed slightly higher values at the age of seven, eight and ten, but significant differences were only recorded in the oldest age group. On average, boys showed greater BMI by 4.39%. The TUA values did not point to a notable difference between boys and girls, while the UMA results were higher in boys of all ages, but without statistical significance. On average, the UMA values were by 6.78% higher in boys than in girls. The opposite trend, however, was evident in case of UFA and

Table 2. Mean, standard deviation and DI of BMI, TUA, UMA, UFA and FM in boys and girls
Tabela 2*. Prosečne vrednosti, standardna devijacija i polni dimorfizam (DI) indeksa BMI, TUA, UMA, UFA i FM kod dečaka i devojčica*

Anthropometric indices *Antropometrijske karakteristike*	Age *God.*	Boys *Dečaci*			Girls *Devojčice*				
		N *Br.*	Mean *Srednje*	SD *Stand. devij.*	N *Br.*	Mean *Srednje*	SD *Stand. devij.*	p	DI % *Polni dimorfizam %*
BMI (kg/m^2)‡ *Indeks telesne mase (kg/m^2)‡*	7	42	17.89	3.74	41	16.67	2.78	0.097	4.40
	8	91	17.29	2.48	86	17.06	2.50	0.535	
	9	91	17.94	2.76	92	17.98[a]	3.31	0.934	
	10	78	19.94[c]	5.05	72	18.27	3.53	0.020	
TUA (cm^2)† *Ukupni obim nadlaktice (cm^2)†*	7	42	29.45	11.17	41	27.62	8.85	0.498	1.48
	8	91	28.57	8.16	86	29.59	8.07	0.395	
	9	91	30.54	9.45	92	32.09	10.27	0.377	
	10	78	39.54[c]	16.31	72	36.92[c]	11.84	0.920	
UMA (cm^2)† *Mišićna masa nadlaktice (cm^2)†*	7	42	18.54	4.56	41	16.81	4.44	0.084	6.79
	8	91	18.06	4.08	86	17.22	3.37	0.138	
	9	91	19.09	4.17	92	18.40	4.62	0.289	
	10	78	22.91[c]	6.57	72	21.17[c]	5.70	0.086	
UFA (cm^2) † *Masna komponenta nadlaktice (cm^2) †*	7	42	10.91	7.34	41	10.80	5.26	0.937	-5.85
	8	91	10.54	4.88	86	12.37	5.82	**0.025**	
	9	91	11.45	6.04	92	13.69	6.50	**0.017**	
	10	78	16.63[c]	10.69	72	15.75[a]	7.61	0.566	
% FM ‡ *Procenat telesne masnoće ruku*	7	42	34.48	9.51	41	37.84	7.86	0.084	-9.87
	8	91	35.47	7.73	86	40.25	8.90	**0.000**	
	9	91	35.58	8.66	92	41.04	8.12	**0.000**	
	10	78	39.05[b]	10.00	72	41.28	8.90	0.152	

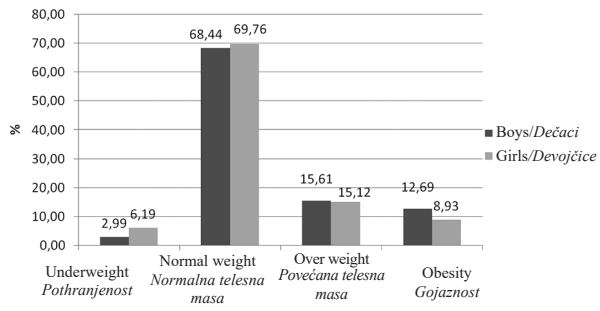
Legend: ‡ t- One-Way ANOVA for Independent Samples (LSD Post Hoc); † Mann-Whitney U test and Kruskal Wallis test; a, b, c – statistically significant increase in relation to the previous year: [a] $p < 0.05$, [b] $p < 0.01$, [c] $p < 0.001$; Bold values are statistically significant
Legenda: *‡ t - jednosmerna ANOVA za nezavisne uzorke (LSD Post Hoc); † Man-Vitnijev U test i Kruskal Valisov test; a, b, c – statistički značajno povećanje u odnosu na prethodnu godinu: a $p < 0,05$, b $p < 0,01$, c $p < 0,001$; Boldovane vrednosti su statistički značajne*

FM% results, as higher values were found in girls of all ages, with significant differences observed at the age of eight and nine ($p < 0.001$). The FM% was on average by 9.86% greater in girls than in boys.

Most subjects had normal weight (**Graph 1**); 15% of boys and girls were overweight, the number of obese was slightly higher in boys (12.96%) than in girls (8.93%), while the number of underweight children was generally low, with girls showing greater percentage (6.19%) than boys (2.99%).

Discussion

This study focuses on the growth, development and nutritional anthropometric status among prepubertal children from North Bačka region using the height, weight and indirect anthropometric measurements of the upper arm. The study shows that in general, at this age, children have similar anthropological characteristics. Over the first decade, the children's growth is almost linear, which is in agreement with other studies [18] and boys and girls accrue lean body mass at similar rates [19]. However, girls show a tendency to get higher percentage of body fat and also show higher TSFT, while BMI is not significantly different, which is in line with other investigations [20, 21]. Compared to previous studies of children of the same age and in the same geographical region, similar values were found for body height, however, the body weight in the studied children shows an upward trend, i.e. the



Graph 1. Distribution of the participants' nutritional status
Grafikon 1*. Struktura ispitivane grupe u odnosu na stepen uhranjenosti*

positive secular trend [22]. In the survey of prepubertal children (8–10 years) from this region conducted 20 years ago, the mean height of boys was 135.25 cm and in girls it was 135.06 cm, which is quite similar to the values recorded in the present survey (135.40 cm and 135.20 cm, respectively). However, the weight values obtained 20 years ago (31.10 and 31.05 kg, respectively) are lower compared with the present results (34.21 and 32.76 kg). The secular trend provides insight into the link between growth and the environment [16] and highlights the complex interplay between genes, physiology and environment in determining the body size and shape of individuals from one generation to the next [23]. This phenomenon is a biological indicator that is used in auxology and for assessing the degree of socio-economic development of a country, which is an important information for public health policies [24]. The positive secular trend has largely been attributed to improved nutrition, health conditions and socio-economic circumstances, while negative secular change in a population's height is a response to environmental deterioration. Many studies of the secular trend have highlighted a progressive decrease of the intensity and speed of growth among the industrialized countries over the last few decades [25], which means that the populations achieved their full genetic potential and/or that their socio-economic conditions had ceased to improve. This investigation shows that the secular trend in height is slowing down or has already ceased. We can assume that this may indicate a stagnation of living standards, and no improvement of environmental conditions in recent decades. The other possible reason is that Serbian population has reached its genetic potential in height and in that case the situation cannot be explained by existing social or economic conditions. In contrast, weight generally continues to increase. The mean BMI is significantly higher today (18.39 kg/m^2 in boys and 17.77 kg/m^2 in girls) than it was 20 years ago (16.82 and 16.71 kg/m^2, respectively). Overall, the prevalence of overweight/obesity in prepubertal children today is 28.57% among boys and 24.05% among girls. The percentage of the underweight is lower, with more girls belonging to this category than boys. According to the data presented in the National Program for Obesity Prevention in Serbian Children and Adults, 70% of children have normal nutritional status, 15% are overweight, 4.9% are obese, and 5% are underweight [26]. In comparison with the findings presented here, the number of overweight children is almost identical, while the number of obese boys and girls is higher in this study. According to the recent investigations in some European countries, the prevalence of overweight and obesity in European children under the age of ten approximately equals 20%, with considerable variations among countries and socio-economic groups [27]. Thus, the prevalence varies from 40% in South Europe to less than 10% in North European countries.

The use of skin-fold thickness in the assessment of nutritional status of children is based on the assumption that increased subcutaneous fat, resulting from high calorie intake or low energy expenditure reflects a greater calorie reserve [28]. This study shows that girls have thicker triceps skinfold than boys, the difference being significant at the age of 8 and 9, while the BMI does not differ, except in 10-year-old children. Compared with previous surveys of children in the same region, when the mean TSFT equaled 10.81 mm in boys and 12.78 mm in girls, the positive secular trend is notable regarding this trait as well [22]. Due to the fact that the thickness of these folds is a measure of the subcutaneous adipose tissue, these data indicate that girls of this age exhibit a significantly higher amount of body fat than their male counterparts. The findings are additionally supported by the FM%, as these values are also higher in girls than in boys of all ages. The results are in line with other studies which show that sex differences in body composition are evident before puberty [29, 30], but opposite to some earlier studies [31] where any sexual dimorphism in body composition was denied up to the onset of puberty. It is well known that adult females have a higher amount of absolute and relative amount of subcutaneous fat tissue, while males have higher amount of fat free mass, i.e. lean body mass, including bone and muscle mass [32]. These differences are mainly due to gender typical secretion of sex hormones. Estrogen has been associated with healthier, peripheral fat distribution in women [33], while testosterone in men has more pronounced effects on visceral adipose tissue and maintains the lean mass [34]. Gender differences in lipid metabolism [35] can also affect differences in body composition. In postnatal life, significant gender differences in sex hormone levels occur not before puberty, and it is considered that gender differences in body composition in prepubertal age are slight [31]. However, some studies have documented that gender differences in body fat and lean body mass are present even at the age between 3 and 10 years [29, 30, 36, 37], and these findings are in line with the results of this survey. Other studies have found statistically significant gender differences in FM% and fat-free mass in full-term newborns, at ~1 month of age, but by 6 months of age, these differences no longer existed [38]. The authors explained that male infants possess less FM% and greater fat-free mass during early development when their testosterone production peaks. When testosterone production decreases at ~3 months of life, body composition between male and female infants no longer differs. Other studies also point out that gender differences appear very early and exist even between newborns, while newborn girls exhibit a significantly higher amount in relative fat mass and a lower amount in lean body mass in comparison to newborn boys [38]. These gender differences in the amount of body fat may also be interpreted as a

result of natural selection, and higher amount of relative fat tissue in prepubertal girls and even during early development, may reflect the preparation of the female body for future reproductive function [30]. According to some authors, gender differences in body fat reflect gender typical energetic demands of reproductive physiology [39, 40]. Sufficient quantities of body fat supply the female body with the energy needed for pregnancy and lactation, while low fat storage has adverse effects on female reproductive success.

Conclusion

The investigation of prepubertal children points to minor differences in anthropological characteristics between boys and girls. Boys show slightly greater height and weight, and the dimorphism index equals 0.43% and 5.25%, respectively. The study shows that the secular trend in height is slowing down or has already ceased. In contrast, weight generally continues to increase resulting in positive secular trends in overweight and obesity. The body mass index shows no significant sex difference, but the findings point to a generally higher percentage of overweight and obese children. Almost 26% of children are overweight. Although boys and girls show no significant differences in anthropological traits and body mass index values, considerable differences are detected in their body composition, thus pointing to the fact that sex differences are present even before the onset of puberty. Considering the present increase in the prevalence of overweight, the assessment and quantification of body composition is extremely important in order to inform the public on possible health risks related to overweight and obesity.

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