Quantitative Sex Differentiation of Morphological Characteristics in Children Aged 11 to 14 Years

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A B S T R A C T

Sex is one of major factors of individual variability. In kinesiology, we explore and record changes brought on by growth and development, so we will use a sample of 1020 subjects, at the age of powerful changes caused by sexual maturation, to investigate differences in morphological characteristics of children and to determine the significance of differences based on sex. The aim of this transversal research was to determine the sex differentiation of morphological characteristics in 5th and 8th grade students of elementary school as well as structural differences between the sexes. Differential sex differences in the structure of morphological parameters surely exist, and in their basis lies in a different temporal, or periodical onset of development phases, while multivariate analysis of variance for each age removes any doubt about these differences being more than obvious. Differences in the structure of discriminant function in children aged 11 are conditioned primarily by diverse structuring of transverse dimensions, in a way that boys are distinctly superior in knee diameter, and girls in bicristal diameter. As early as the age of 11, it can clearly be recognized that pre-puberty had already progressed in girls, which is then followed by puberty. At the age of 12 girls are already experiencing a puberty spurt, which is manifested in further development of bicristal diameter and longitudinal dimensionality of the skeleton, particularly of lower extremities. Thirteen year old boys are on the verge of a puberty spurt, which is manifested through the development of longitudinal dimensionality, and to a lesser extent, of transverse dimensionality of the skeleton. Secondary discriminant distinctiveness can be observed continuously across all variables assessing the dimension of deposition of fat reserves, and also, absolute values of measures of subcutaneous fat tissue are more prominent in female students. It is indicative that subcutaneous fat deposits are still secondary determinants in distinguishing groups of children according to sex, in a way that this dimension is continuously expressed more perceptibly in girls.

Key words: *growth, development, sexual dimorphism, morphological characteristics, puberty*

Introduction

Differences between the sexes are called sexual dimorphism, and sex differences are biologically conditioned. Concept of »sexual dimorphism« is defined as »the existence of attributes which indicate a distinct difference between males and females of the same species according to form (shape)«[1].

Developmental age or physiological maturity or biological age show where a person currently is on its way to maturity much better than chronological age, because the pace is different for persons of the same sex from the very birth just as there are differences between the sexes[2,3]

The concept of maturation implies the dynamics of change and progress until reaching biological maturity[4,5]. The puberty is a particularly dynamic period of growth and maturation characterized by changes of linear growth, proportions and body composition, and by the development of secondary sexual characteristics[6]. There is also great variability regarding the onset of puberty[7,8], both in dynamics and duration, but also within the same sex. Therefore, puberty in girls begins in a wide age range of 9–13 years, and in boys at the age of 10–14, until the maturity status[9,10].

Bala and Katić used a large sample of 1170 children, 565 boys and 605 girls aged 4 to 7.5 decimal years from preschool institutions to analyze the conditions and differences according to age between boys and girls. Generally significant differences were determined in anthro-

pometric characteristics relating to longitudinal bone growth in favor of the boys, and those relating to voluminosity and subcutaneous fat in favor of the girls[11].

Based on the research of morphological space on a sample of 312 subjects aged 11 to 14, Pavić identified two types of development processes in students of both sexes, these being the processes related to longitudinal and transverse skeleton development and processes related to regulation of muscle and fat tissue ratio. Certain specificities according to sex were also established. In boys, the first factor is responsible for skeleton development followed by muscle tissue development, whereas in girls, the first factor is defined by fairly high projections of morphological measures for assessing subcutaneous fat tissue and measures for assessing body mass and volume[12].

Momirović, Hošek and Popović addressed the issue of sexual dimorphism in older people across their papers collected in a monograph called »Sexual dimorphism«[13]. The monograph considers only one segment of the anthropological space of man: cognitive abilities and conative characteristics, as well as aberrant behavior and their mutual relations. These papers point out the differences and issues in sexual dimorphism of adults, which can be used indirectly to explain the sexual dimorphism in children[14].

This research was conducted on a sample of children aged 11, 12, 13 and 14, and in this sample it is expected for sexual dimorphism to start developing differences in a variety of characteristics, and obtained differences will be presented according to sex and age.

Subjects and Methods

Subject sample

The subject sample included 1020 subject, i.e. children of both sexes, 5th to 8th grade students attending primary schools »Marjan«, »Split 3« and »Ravne Njive« in Split, who will, at the beginning of the experimental process, have been aged 11, 12, 13 or 14 ± 2 in relation to the grade.

The subject sample was divided according to age and sex:

Students attend classes regularly, two classes of 45 minutes a week, some of them participate in extracurricular sports activities, and some children also practice sports in their own free time outside school. Extracurricular activities are integral part of educational structure in primary school and they include different program contents aimed at satisfying students' real needs and interests, and also teaching how to take better care of one's health.

Variable sample

Variable sample for assessing morphological characteristics included 14 anthropometric measures[15], measured according to the guidelines given by the International Biological Program (IBP): Body height (mm), Leg length (mm), Arm length (mm), Bisacromial diameter (mm), Bicristal diameter (mm), Wrist diameter (mm), Knee diameter (mm), Body weight (dkg), Forearm circumference (mm), Lower leg circumference (mm), Thorax circumference (mm), Triceps skinfold (1/10 mm), Back skinfold (1/10 mm), Abdominal skinfold (1/10 mm).

Data analysis

Basic statistical parameters were calculated for all groups of study subjects *per* variable (mean and standard deviation). The significance of quantitative differences in the overall space of variables was defined from the results of univariate analysis of variance (ANOVA). Canonical discriminant analysis was used to determine the differences between groups of subjects, and Statistica software for Windows 8.0 was used for statistical analysis.

Results

Values of descriptive parameters in both groups of subjects (boys and girls), variables for assessing morphological characteristics in Tables 1 and 2 do not deviate from normal distribution and enable further development of scientifically valid data.

Obtained results of discriminant functions are presented with the purpose of obtaining information about quantitative sex differentiation of morphological characteristics of boys and girls at given points of time.

Discussion

This research has determined sex differentiation of morphological development in school children at the age of 11 to 14, and identified differences of development and/or integration functions in relation to sex. Variance analysis was used to determine quantitative indicators of morphological development between groups of children of different age, while canonical discriminant correlation analysis was used to determine differences between the sexes in particular age groups.

Based on variance analysis between age groups in boys, it can be assumed that between the ages of 11 and 12, there is a moderate increase in longitudinal growth of the skeleton, and a much lesser transverse growth, which is accompanied to a lesser extent by muscle tissue growth. Intensive development occurs between the ages of 12 and 13, especially of longitudinal and transverse dimensionality of core skeleton and skeleton of upper extremities, which is accompanied to a great extent by muscle mass development, whereas between the ages of 13 and 14, a more intensive development of longitudinal dimensionality of skeleton of the extremities occurs, also accompanied to a large extent by muscle mass development. Based on variance analysis between age groups in girls, it can be assumed that intensive development occurs between the ages of 11 and 12, especially of longitudinal dimensionality of the skeleton which is accompanied to a great extent by muscle mass development,

TABLE 1
BASIC STATISTICAL PARAMETERS OF MORPHOLOGICAL VARIABLES IN BOYS AGED 11 TO 14

Variable	11 (N=122)	12 (N=119)		13 (N=112)		14 (N=100)	
	X±SD	X±SD	p	X±SD	p	X±SD	p
Body height	153.80±6.76	158.65±7.51	a	169.01±8.50	a	173.29±7.67	a
Leg length	87.85±4.82	91.24±5.51	a	94.17±7.98	a	100.50±4.59	a
Arm length	67.18±3.68	70.59±4.81	a	73.38±4.37	a	77.50±4.42	a
Bisacromial diamet.	32.73±1.97	33.83±1.86	a	36.33±2.81	a	36.89±2.48	
Bicristal diameter	24.75±2.08	25.24±1.94		27.35±2.80	a	27.03±2.16	
Wrist diameter	4.98±0.45	5.14±0.44	b	5.77±1.06	a	5.53±0.35	c
Knee diameter	9.23±0.71	9.49±0.65	a	9.42±0.88		9.97±0.49	a
Body weight	44.45±8.81	49.13±9.03	a	56.93±11.63	a	64.61±10.26	a
Forearm circumfer.	21.20±1.78	21.89±2.06	b	22.98±2.18	a	24.71±2.00	a
Lower leg circumf.	32.24±3.48	33.09±3.15		34.53±3.24	a	36.04±2.70	a
Thorax circumfer.	73.62±7.69	76.15±7.43	b	80.11±7.54	a	86.01±6.12	a
Triceps skinfold	11.86±5.29	12.42±5.76		10.95±4.96		10.98±4.51	
Back skinfold	9.29±5.25	10.26±6.05		8.41±3.44	b	9.55±3.96	
Abdominal skinfold	14.58±9.19	14.76±9.17		12.58±7.73		12.91±7.27	

Significance of differences in relation to the previous age: [a]p<0.001, [b]p<0.01, [c]p<0.05

TABLE 2
BASIC STATISTICAL PARAMETERS OF MORPHOLOGICAL VARIABLES IN GIRLS AGED 11 TO 14

Variable	11 (N=167)	12 (N=129)		13 (N=117)		14 (N=154)	
	X±SD	X±SD	p	X±SD	p	X±SD	p
Body height	153.62±6.70	160.36±6.78	a	164.81±5.81	a	168.05±5.44	a
Leg length	88.71±4.76	93.21±4.50	a	93.50±5.35		95.34±4.01	a
Arm length	67.03±3.96	70.35±3.44	a	71.47±3.36	b	73.20±3.02	a
Bisacromial diamet.	32.30±1.98	33.88±1.89	a	34.56±1.97	b	34.54±2.13	
Bicristal diameter	25.69±2.63	26.31±1.91	c	27.15±2.48	a	26.85±2.79	
Wrist diameter	4.90±0.33	5.05±0.35	a	5.29±0.78	a	5.23±0.41	
Knee diameter	8.83±0.62	8.96±0.63		9.16±0.87	c	9.28±0.61	
Body weight	44.68±8.99	49.04±8.03	a	55.63±10.05	a	57.94±8.97	c
Forearm circumfer.	20.67±1.75	21.25±1.63	b	22.35±2.13	a	22.54±1.77	
Lower leg circumf.	31.58±3.17	33.15±2.83	a	34.48±3.89	a	34.99±2.94	
Thorax circumfer.	72.88±7.22	77.55±7.77	a	81.38±8.35		82.53±7.29	
Triceps skinfold	12.07±4.50	11.95±3.91		11.72±5.77		12.05±5.03	
Back skinfold	9.72±5.11	10.25±3.99		11.66±5.55	c	10.91±3.73	
Abdominal skinfold	14.49±7.45	15.00±6.51		16.11±6.72		16.65±6.39	

Significance of differences in relation to the previous age: [a]p<0.001, [b]p<0.01, [c]p<0.05

significant development of body mass and volume as well as of body height occurs between the ages of 12 and 13, accompanying the transverse development of the skeleton, and intensive development of longitudinal dimensionality of the skeleton continues between the ages of 13 and 14.

Morphological development between the ages of 11 and 14, both in male and female children, is reflected onto sex morphological differentiations at a particular age[16,17].

Sex differentiations of morphological characteristics between the ages of 11 and 14:

– at the age of 11, boys, in relation to girls, have a greater knee diameter and forearm circumference, whereas girls, in relation to boys, have a greater bicristal diameter;

– at the age of 12, boys, in relation to girls, have a significantly greater knee diameter and, to a lesser extent, a greater forearm circumference, whereas girls,

in relation to boys, have a significantly greater bicristal diameter and longer legs;

– at the age of 13, boys, in relation to girls, have a significantly greater bisacromial diameter, body height, arm length and arm wrist diameter, and to a lesser extent, a greater forearm circumference and knee diameter, whereas girls, in relation to boys, have significantly more fat tissue, especially on the back and abdomen;

– at the age of 14, boys, in relation to girls, show even more prominent differences in longitudinal measures of the skeleton, particularly of extremities, in transverse measures of the skeleton, particularly of knee diameter and in measures of body mass and volume, particularly of forearm circumference, whereas girls, in relation to boys, have more fat tissue, especially abdominal.

Conclusion

The structure of discriminant function in children aged 11 is conditioned primarily by diverse structuring of transverse dimensions, in a way that boys are distinctly superior in knee diameter, and girls in bicristal diameter. It can also be noticed that primary elongation in girls was gained at the expense of lower extremities. Certainly, the angle of the hip-knee-foot line is changed, with this line being much more dented at the knee joint. Increased

lateral pressure will change not only the type of support, but also the actual leg structure, which is largely connected to the future female function to be expected in motherhood[18].

However, it is interesting that all this can be recognized as early as the age of 11, which clearly indicates the progression of pre-puberty in girls, which will be followed by puberty. At the age of 12 girls are already in puberty spurt, which is manifested in further development of bicristal diameter and longitudinal dimensionality of the skeleton, particularly of lower extremities, whereas development of the knee joint and forearm circumference is still manifested in boys. Thirteen year old boys are on the verge of a puberty spurt, which is manifested through the development of longitudinal dimensionality, and to a lesser extent, of transversal dimensionality of skeleton. Secondary discriminative particularity can be observed continuously across all variables assessing the dimension of deposition of fat reserves. In regard to group centroids, it is evident that girls are more prone to adiposity than boys[19], and absolute values of subcutaneous fat tissue measures are more prominent in female students[20]. This situation can be explained if we recall a well-known fact about movement insufficiency of female students[4] and a parallel process of inadequate diet, primarily of food determined by unsuitable composition of nutrients[21] primarily the lack of protein and overuse of carbohydrates which are difficult to resolve, but also exposure to

TABLE 3
SEX DIFFERENTIATIONS (DF) OF MORPHOLOGICAL CHARACTERISTICS IN CHILDREN AGED 11 TO 14

Variable	11 (N=289)		12 (N=248)		13 (N=229)		14 (N=254)	
	DF	p	DF	p	DF	p	DF	p
Body height (mm)	–0.02		0.15	G[b]	0.36	B[a]	–0.32	B[a]
Leg length (mm)	0.15		0.25	G[a]	0.06		–0.48	B[a]
Arm length (mm)	–0.03		0.02		0.31	B[a]	–0.47	B[a]
Bisacromial diameter (mm)	–0.19	B[b]	0.02		0.46	B[a]	–0.41	B[a]
Bicristal diameter (mm)	0.33	G[a]	0.35	G[a]	0.05		–0.03	
Wrist diameter (mm)	–0.18	B[b]	–0.15	B[b]	0.32	B[a]	–0.30	B[a]
Knee diameter (mm)	–0.51	B[a]	–0.55	B[a]	0.19	B[b]	–0.48	B[a]
Body weight (dkg)	0.02		–0.01		0.07		–0.28	B[a]
Forearm circumference (mm)	–0.25	B[a]	–0.23	B[a]	0.18	B[b]	–0.46	B[a]
Lower leg circumference (mm)	–0.17		0.01		0.01		–0.15	B[b]
Thorax circumference (mm)	–0.08		0.12		–0.10		–0.20	B[a]
Triceps skinfold (1/10 mm)	0.04		–0.06		–0.09		0.09	
Back skinfold (1/10 mm)	0.07		0.00		–0.44	G[a]	0.14	G[b]
Abdominal skinfold (1/10 mm)	–0.01		0.02		–0.31	G[a]	0.22	G[a]
Centroids:								
Girls	0.51		0.76		–0.78		1.00	
Boys	–0.69		–0.82		0.81		–1.54	
Can R	0.51		0.62		0.62		0.78	

DF – structure of discriminant function, p-level – significance level, B – Boys, G – Girls, [a]p<0.01, [b]p<0.05, Centroids – centroids, Can R – canonical discrimination coefficient

various acute illnesses (hygienic conditions, endemic diseases…)[22]. It is indicative that subcutaneous fat deposits are still secondary determinants of distinguishing groups of children according to sex, in a way that this dimension is continuously expressed more obviously in girls.

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KVANTITATIVNE SPOLNE DIFERENCIJACIJE MORFOLOŠKIH KARAKTERISTIKA KOD DJECE OD 11 DO 14 GODINA

SAŽETAK

Spol je jedan od značajnih čimbenika interindividualne varijabilnosti. U kineziologiji istražujemo i bilježimo promjene izazvane rastom i razvojem pa ćemo na uzorku od 1020 ispitanika, u periodu kad su prisutne snažne promjene izazvane spolnim sazrijevanjem, istražiti razlike morfoloških karakteristika djece te utvrditi značajnost razlika temeljem spola. Ovo transverzalno istraživanje ima cilj utvrditi spolne diferencijacije morfoloških karakteristika učenika od petog do osmog razreda osnovne škole te utvrditi strukturalne razlike između spolova dječaka (N=453) i djevojčica (N=567). Diferencijalne spolne razlike u strukturi morfologijskih parametara zasigurno postoje i u njihovoj osnovi je različito vremensko, odnosno periodično, uključivanje razvojnih faza, a multivarijantna analiza varijance za svaku pojedinu starosnu dob: u 11, 12, 13 i 14 godini, ne ostavlja ni traga sumnji u to da su razlike više nego evidentne. Struktura diskriminativne funkcije kod djece od 11 godina, orijentirana je tako da primarnu diskriminativnu ulogu dodjeljuje parametru dijametar koljena i u znatno manjoj mjeri biakromijalnom dijametru i dijametru ručnog zgloba, te opsegu podlaktice i potkoljenice u korist dječaka, a bikristalnom dijametru te dužini noge u korist djevojčica. Ovo znači da su razlike u strukturi primarno uvjetovane različitim strukturiranjem transverzalnih dimenzija, i to na način da su dječaci izrazito superiorni u dijametru koljena, a djevojčice u bikristalnom dijametru. Već u uzrastu od 11. godina može se jasno prepoznati kako je predpubertet u djevojčica već uznapredovao, i da slijedi pubertet. U 12. godini djevojčice su već u pubertetskom zamahu, što se očituje u daljnjem razvoju bikristalnog dijametra i longitudionalne dimenzionalnosti skeleta posebno donjih ekstremiteta. Kod dječaka u 13. godini slijedi pubertetski zamah, što se očituje u razvoju longitudinalne dimenzionalnosti, a manje transverzalne dimenzionalnosti skeleta. Sekundarna diskriminativna osobitost je primjetna kontinuirano preko svih varijabli za procjenu dimenzije deponiranja masnih rezervi, a i apsolutne vrijednosti mjera potkožnog masnog tkiva izraženije su kod učenica. Indikativno je kako su i dalje sekundarne odrednice razlikovanja grupa djece po spolu upravo masni potkožni deponiji, i to na način da djevojčice konstantno ovu dimenziju iskazuju znatno očitije.