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Influence of Age and Sex on the Growth of Different Body-segments in 9-15-Year-old Schoolchildren from Sofia (Bulgaria)

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During the intensive morphological growth in the puberty, the age and sex (both as main effects and in their interactions) play an important role in the phenotypic trait development. In the present report we analyze data on the influence of age and sex on the dimensionality of 15 main height-length, width, and circumferential anthropometric features in 9-15-year-old boys and girls from Sofia (Bulgaria). The influence of both factors on the morphological growth was estimated by MANOVA. The results indicate that almost all of the morphological features are statistically significantly influenced by age and sex. The interaction of these factors has been found to be statistically significant for 10 of the measured features. So the growing boys are on average higher, have longer body parts, as well as larger chest circumference and breadth, wider shoulder and pelvic girdles, and a larger forearm circumference compared to the growing girls.

Key words: adolescents, age, sex, interactions, growth, anthropometric features.

Introduction

The age and sex of an individual are important factors for its anthropological characterization during the various periods of its ontogenetic development. During the growth phase these factors play an important role in the formation of the specific features of the male and female body composition type [4,11, 12, 13,14, 20, 30, 31, 33]. The processes of growth and development at a young age are important for changes occurring in the aging of the body – involutive processes, functional specificity and morbidity [1, 16, 17, 18]. Significant role in the formation of somatic features of the organism during growth and development play various genetic and exogenous factors – biogeographical,

socio-economic and demographic, nutrition and physical activity [1, 3, 8,11, 24, 25, 26, 27, 28, 30, 32]. Under favorable conditions, the possibility of full realization of the hereditary potential of the organism is better. A number of authors have sought to find the link between human morphology and disease, to identify those external factors and habits that are at risk for human health and cause premature aging [1, 3, 16,17,18, 19]. Somatometric sex differences are also known to be present in newborns and continue to exist throughout the growth period [12, 13, 15, 21, 24, 27, 28]. Most vividly, however, they emerge during pubertyinmajor length-, width-, and circumference-based features of the body [2, 5, 6, 9, 13,14, 22, 23, 29, 31]. Based on the fact that one of the main characteristics of the growth process that reflects age dynamics well is speed, many authors estimate the growth rate by the absolute and relative annual growth of a number of anthropometric features and indices [11, 12, 13, 14, 20, 21, 22, 31].

From a mathematical point of view, a well-suited statistical approach forcapturing the influences of two or more factors (and in their interaction) on several biometric features is the multifactorial variant of ANOVA – MANOVA. In the available literature we have not encountered studies using such analysis of the influence of age and sex as independent factors and in their interaction.

The **aim** of the present work is to assess the morphological specificity of the growth process of the different body parts and areas in the studied subjects, depending on their age and sex (incl. their interaction) by MANOVA in 9-15-year-old children and adolescents from Sofia.

Material and methods

The data analyzed are part of a complex cross-sectional anthropological study including 1142 schoolchildren (569 boys and 573 girls) aged 9-15 years from three schools in Sofia city, carried out during the years 2001 and 2002 [10]. The schoolchildren and their parents volunteered for the research and gave their written informed consent. The boys and girls under investigation were separated uniformly each sex in seven age groups – mean ages of 9.5, 10.5, 11.5, 12.5, 13.5, 14.5 and 15.5 years. The groups of the 9-year-old children comprise 81 boys and 81 girls, aged from 9.00 years to 9.99 years. The rest investigated boys and girls were ranged according to the same age affiliation.

We included in the MANOVA analysis data on 15 directly measured anthropometric features (**see Table. 1**) of the trunk and extremities measured by standard anthropometric method [7]. All measurements were made on the right side of the body by standard anthropometric instruments in centimetres (cm).

The significance of the influence of both factors individually, and in their interaction (noted as **age & sex**) on the metric differences in the anthropometric features included in our MANOVA-model has been objectified by the respective levels of statistical significance as expressed by the F-ratio of the Pillai's test ($p<0.010$) and by SPSS software, version 16.0.

Results and Discussion

Validating the differences in the corresponding mean values between the groups in both the growth- as well as in the main lengths, breadths and circumferential features of the body in 9–15-year old children and adolescents, statistically reliable dependencies (at a very high level of statistical significance, $p < 0.000$) have been found even by using the Pillai's test (**Table 1**).

Table 1. Statistically significant levels concerning the effect of the tested factors on the size of various anthropological features.

	Factors	***Sex***		***Age***		***Sex & Age***	
№	***Features***	***F***	***p<***	***F***	***p<***	***F***	***p<***
1	Stature- **St**	19.357	0.000	322.685	0.000	13.632	0.000
2	Anteriortrunk length – **ATrL**	48.728	0.000	206.694	0.000	10.816	0.000
3	Upper extremity length – **Upp.EL**	53.992	0.000	230.697	0.000	11.359	0.000
4	Lower extremity length – **Low.EL**	29.376	0.000	237.460	0.000	14.664	0.000
5	Biacromial breadth – **BAB**	59.750	0.000	218.989	0.000	12.631	0.000
6	Bicristal breadth – **BCB**	12.139	0.001	118.191	0.000	3.215	0.004
7	Chest breadth on the level of *mst* – **ChB**	43.936	0.000	99.630	0.000	4.046	0.001
8	Sagittal chest breadth (Chest depth) – **SChB**	45.370	0.000	66.790	0.000	5.048	0.000
9	Chest circumference in pause – **ChCP**	76.092	0.000	61.613	0.000	7.846	0.000
10	Waist circumference – **Waist C**	38.471	0.000	29.785	0.000	1.900	0.078
11	Hip circumference – **Hip C**	24.666	0.000	108.412	0.000	0.592	0.737
12	Thigh circumference – **Thigh C**	22.756	0.000	57.454	0.000	0.370	0.898
13	Upper arm circumf. (relaxed) – **Upp.AC**	6.642	0.010	43.031	0.000	1.943	0.071
14	Forearm circumference – **FAC**	58.429	0.000	81.850	0.000	5.295	0.000
15	Middle calf circumference – **Mid. Calf C**	0.321	0.571	64.525	0.000	1.167	0.322

Pillai's test (p < 0.010)

Results show that all anthropometrical features analyzed were significantly influenced by the **age** factor. Of the **sex** factor were significantly influenced all, except middle calf circumference.

Of the fifteen anthropometric features tested by our MANOVA model, only ten – St, ATrL, Upp.EL, Low. EL, BAB, BCB, ChB, SChB, ChCP и FAC – have been found to be influenced by the interaction of **age & sex**.

Globally, this means that adolescents of one sex (i.e., males) aged between 9 and 15 years normally reach a greater body-height and generally larger sizes of: 1) the chest (incl. chest circumference in pause), 2) width of shoulders and pelvis, 3) anterior trunk length, 4) upper and lower extremities, and 5) forearm circumference, as compared to their teenage peers of the opposite sex – females.

The established relationship is considered to be genetically determined and has been associated with the longer duration of puberty in boys, as well as with their greater motor activity [5, 28, 29]**.**

The remaining circumference-based features Hip C, Thigh C, Upp.AC and Mid. Calf C as examined in adolescents between 9 and 15 years of age were reliably influenced by the specific effects of age and sex (separately, as individual factors), except for Mid. Calf C, where growth-changes according to the MANOVA-analysis were influenced only by age.

Interestingly, the consistency of the magnitude of differences between the minimum and maximum mean values of the features in our sample of schoolchildren aged from 9 to 15 years (i.e., the absolute increase in the feature between the 9th and 15th year) reflected the impact of age on metric differences in each individual characteristic.

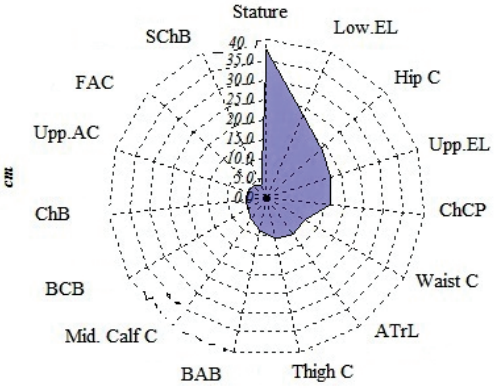

Fig. 1. Sequence of features in boys between 9 and 15 years of age according to the influence of the age factor.

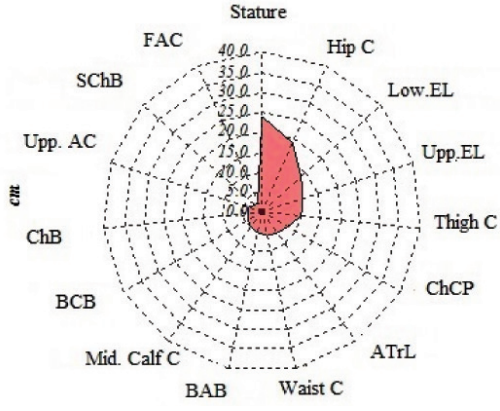

Fig. 2. Sequence of features in girls between 9 and 15 years of age according to the influence of factor age.

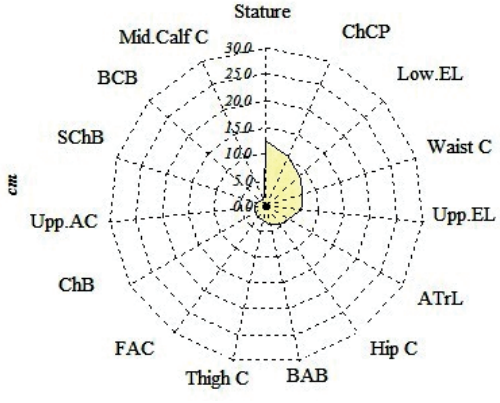

Fig. 3. Sequences of features inter both sexes (between 9 and 15 years of age) according to their minimum and maximum average difference.

In **boys** we found the sequence of features to be as follows **(Fig. 1)**: St > Low.EL > Hip C > Upp.EL > ChCP > Waist C > ATrL > Thigh C > BAB > Mid. Calf C > BCB > ChB > Upp.AC > FAC > SChB.

In **girls** the sequence was **(Fig. 2)**: St > Hip C > Low.EL > Upp.EL > Thigh C > ChCP > ATrL > Waist C > BAB > Mid. Calf C > BCB > ChB > Upp. AC > SChB > FAC.

The sequence of features, according to their maximum differences in mean values **between sexes** across the surveyed age-range, thus reflecting the influence of sex on the growth-changes at each individual size-class, is as follows **(Fig. 3)**: St > ChCP > Low. EL > Waist C > Upp.EL > ATrL > Hip C > BAB > Thigh C > FAC > ChB > Upp. AC > SChB > BCB > Mid. Calf C.

The analysis of the results shows that in the formation of inter-age morphological differences in adolescents of both sexes, along with the growth and the length-based measurements, the circumferential features in the area of the hip, thigh, chest and waist were also decisive. In adolescents of both sexes, the measurements of the shoulder girdle, the chest and the pelvis, the circumferences of the upper and the lower extremities, respectively, had a relatively smaller but important role in the formation of the inter-age differences.

For the formation of differences between the sexes in respect to the anthropometric characteristics, most decisive were the stature as well as the circumferential measurement of the chest, waist and hip, along with the other length-based measurements (Low. EL, Upp.EL, and ATrL, respectively), followed by the biacromial breadth. According to the MANOVA analysis, the middle calf circumference didn't contribute significantly to the differentiation between sexes as measured in the studied population of schoolchildren of age between 9 and 15 years.

When comparing the influence of age and sex (over the period between 9 and 15 years of age), roughly equal influence among both sexes were found to have only the circumferential dimensions in the area of the hip and thigh.

From the illustration in **Fig. 4** it can be seen that among the rest of the features, age has a significantly greater impact on boys than on girls **(see also Table 1)**.

In addition, we found that sex has a greater impact on growth changes in the hip circumference than in the thigh circumference, and that the increase in both body measurements was independent of the joint influence of sex and age. This fact most probably determines the larger circumferential dimensions of the hip and thigh in girls and the tendency to reduce age-related differences in thigh circumference in adolescents [10].

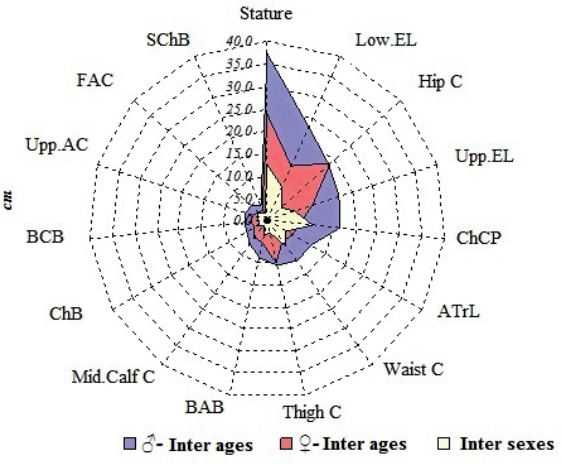

Fig.4. Comparison of the influence of age between 9 and 15 years in the formation of basic metric differences in adolescent boys and girls, and in them inter sexual differences from 9 to 15 years of age.

The results of our study are in line with the results of a number of foreign and Bulgarian researchers, who conducted transversal and/or longitudinal investigates [2, 4, 5, 11, 12, 13, 14, 19, 20, 21, 22, 23, 29, 31, 33]. In general, the authors estimate the growth rate by absolute and relative annual growth of a number of anthropometric features over a broad generalized age range (0 to >22 years), taking into account that, with the exception of pre-pubertal age groups, boys have a greater absolute increase in most of the studied features from that of the girls. High growth velocity was found in both sexes in weight, height, limb length, anterior trunk length, and shoulder width, while width and circumference of the chest and pelvic width showed less growth. Some studies seek for the relationship between puberty, initial body height and limb growth, the latter of which most strongly change their proportions as they grow. The conclusion is that in late puberty and low initial growth, the growth of the limbs and their segments is large, and in early puberty with high initial stature the growth is small.

In conclusion, the scientific contribution of the applied analysis to our study is that **1)** it provides an opportunity to assess separately and in interaction the role of the keys factors responsible for growth and development – age and sex and **2)** to evaluate the phenotypic effect of their impact in the formation of sexual differences in the transformation of the body during pre-puberty and puberty.

The results show that:

- All anthropometrical features analyzed were significantly influenced by the **age** factor;
- Of the **sex** factor were significantly influenced all, except middle calf circumference;
- The interaction between **age & sex** additional determines that male adolescents reach significantly larger height and length-based dimensions of the body, larger diameter and circumference of the chest, shoulder and pelvic girdle width, as well as a larger forearm circumference as compared to their adolescent female peers;

➢ From the combination of the two factors (**age & sex**), apart from calf circumference are not significantly affected also dimensions of the waist, hip, thigh and upper arm – relaxed.

➢ The size of the other circumferential dimensions that we have analyzed was influenced separately by **age** and by **sex**, while both these factors influenced relatively more equally both sexes only in the areas of hip and of the thigh.

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