Morphofunctional characteristics of the students of Moscow Suvorov Military School

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Background. Analysis of factors determining patterns of growth processes in adolescents still remains a matter of great interest. One of the possible ways to identify those factors is to carry out a comparative group analysis, where living conditions may be regarded as relatively standard and regulated in respect of food structure and calorie content, motion activity level etc. This approach may be realized in the study of children from specialized educational institutions.

Materials and methods. In 2006, 255 boys aged from 14 to 17 were investigated cross-sectionally in Moscow Suvorov Military School (SMS). The results were compared with the previously investigated students of Moscow municipal schools and those of special sports schools of the same age range. The program included anthropometric measurements, evaluation of sexual maturation indices, somatotypes, diastolic and systolic blood pressure, pulse rate, hand grip etc. For the study of body composition, the bioelectrical impedance analysis (BIA) was used.

Results. Significant differences were found in somatic and functional traits between the three groups studied. These differences were explained in the first place by social and demographic factors that influenced the samples under analysis. 75% of children in the 1st and 2nd groups were represented by those born in Moscow, while in the 3rd group (SMS) a similar figure equaled only 15%.

Conclusions. Thus, social factors have determined the differences in the course of micro-evolutionary changes between groups: in particular, the brachimorphic body build and brachicephalization in SMS group as compared to the students from the other two groups.

Key words: auxology, physical development, body composition, students of military schools, social factors

INTRODUCTION

In the history of anthropology, a large body of data concerning population differences in body dimensions was based on the studies of recruits and military personnel. Among the first data of the sort is the study of recruits' height in Norway in 1741 (1, 2), although as early as the beginning of the 18th century a minimal low level of height for recruits equal to 5 feet 5 inches was established in England (3). Further, during the period of the 18th, 19th and 20th centuries, measurements of recruits were conducted with remarkable regularity practically in all the countries of Europe and in the United States. In 1779 in Germany, the great poet and public figure Johann Wolfgang von Goethe, who served at the court of the Duke Saxe-Weimar, was made responsible for the enrollment and examination of recruits (4). In the US in 1917–1918, examination of 2 000 000 military men at the age of 21–30 was performed, with the birthplace and race characteristics being taken into consideration (5). Strong social differences were revealed, as even the tallest ones among military (white people born in Texas) were 2.7 cm shorter than graduates from American private schools.

Observations of students of military higher schools were carried out in many countries, including Russia. Thus, at the end of the 19th century, body dimensions of Moscow cadets were measured. Body length of 20-year-old cadets appeared to be 169.2 cm, while the corresponding value for the university students was 170.2 cm, graduates from boarding schools were 168.7 cm, and Moscow factory workers of the same age were 164.2 cm tall (6). Thus, a clearly expressed social gradient confirmed the idea that the cadets belonged to a group with rather high social position.

Studies of recruits served as a basis for detailed analysis of geographic distribution of physical parameters in the population of the Russian Empire, which was carried out by the founding fathers of the Russian anthropological school Anuchin (7), Chepurkovsky (8), Bounak (9) and others.

In recent years, Deryabin and Purundzhan (10) have been dealing with the analysis of geographical variations of body parameters in recruits from different areas of the former USSR (1990); in 2003 Mironov (11) used the data on recruits’ stature for studying secular changes in Russia for the last 200 years.

However, data on children and adolescents studying in military institutions in modern Russia are practically absent, so the
The main goal of the study was to analyze somatic development of students in a specialized military school named after the great 18th century Russian commander Alexander Suvorov (further, this school will be addressed as Suvorov Military School, or SMS), and to compare the results with other groups of contemporary Moscow children. The Suvorov Military School is one of the oldest institutions of this kind in Russia; it enrolls students from age 14; it is a male boarding school; up to 30% of boys are from the families of professional army officers; many are non-Muscovites; after the graduation students enter special higher military educational institutions (academies, universities etc.).

Reasons for sending children to military schools could be different: prolongation of a family tradition, prospects for making a professional career at the absence of other possibilities, or means for obtaining appropriate civil education etc. These factors, as well as other social conditions, such as strict discipline, organized day schedule, regular food intake and physical exercise, form a specific environment that influences growth and development patterns in the students of military schools, as compared to those being educated in ordinary civil schools.

**MATERIALS AND METHODS**

In 2005–2006, 474 boys at the age of 14–17 studying in different Moscow schools have been investigated cross-sectionally: 112 schoolchildren of an ordinary municipal school (group 1); 107 students from a sports school (group 2), in which all the subjects were qualified sportsmen with high ranking in sports; and 255 students of SMS (group 3). All the examined were of the same ethnicity (Russians). The distribution of the investigated children according to their age and school type is given in Table 1.

It is important to mention that in group 3, the SMS students, the number of those born outside of Moscow was 3–4 times higher than in the first two groups, and vice versa for those born in Moscow (Table 2).

Anthropometric program included about 30 measurements taken according to the standard techniques (12, 13). Subjects were measured bare-foot, wearing only underwear. Weight was taken using a battery-operated digital weighing scale (precision 100 g).

Height, arm and leg length (the sum of the heights of iliospinal and symphysis points divided by two) were measured using an anthropometer (1 mm precision). Body diameters (biliac, bicrystal, chest width and chest depth) were measured using a spreading caliper (1 mm precision). Chest circumference was measured at the union of the 3rd and 4th sternebrae. Subcutaneous skinfolds (subscapular, biceps, triceps, forearms, abdomen, suprailiac, thigh and calf) were measured using a skinfold Harpenden caliper (1 mm precision). Elbow, wrist, knee and ankle widths were measured using a special sliding caliper (1 mm precision).

The body mass index (BMI) of the subjects studied was calculated as weight (kg) divided by height$^2$(m$^2$).

Cephalic index was calculated as head breadth divided by head length $\times100$.

Total fat (fat mass) was calculated by Matiegka’s equations (14):

$$FM = d \cdot S \cdot k,$$

where $FM$ is fat mass (kg), $d$ is average thickness of subcutaneous skinfolds (mm), $S$ is body surface (cm$^2$).

Fat-free mass (FFM) was calculated as body mass minus fat mass (FM).

Besides anthropometric measurements, stages of secondary sexual characteristics were evaluated (15).

Diastolic and systolic blood pressure (BP), pulse rate, body temperature and dynamometry, or hand grip (both hands) were measured in all the children. In the text they are called "functional traits".

For the bioelectric impedance analysis, a single-frequency system ABC-01 Medass (16) was used. It operates with a frequency of 50 kHz and is analogous to other systems of that sort. It uses four electrodes attached to the hand and ipsilateral foot in the standard fashion (17).

Bioelectric impedance analysis shows three indices of tissue resistance (impedance): active resistance (AR); reactive resistance or reactance ($Z\prime$), and phase angle ($\phi$). AR is positively connected with fat mass (FM) and negatively with total body water (TBW) and fat-free mass (FFM): the bigger the AR value, the

<table>
<thead>
<tr>
<th>Age</th>
<th>Municipal school (group 1)</th>
<th>Sports school (group 2)</th>
<th>SMS (group 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>14-year-olds</td>
<td>36</td>
<td>39</td>
<td>27</td>
</tr>
<tr>
<td>15-year-olds</td>
<td>44</td>
<td>16</td>
<td>67</td>
</tr>
<tr>
<td>16-year-olds</td>
<td>21</td>
<td>24</td>
<td>92</td>
</tr>
<tr>
<td>17-year-olds</td>
<td>11</td>
<td>28</td>
<td>69</td>
</tr>
<tr>
<td>Total</td>
<td>112</td>
<td>107</td>
<td>255</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Groups 1–2</th>
<th>Group 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moscow</td>
<td>74.8</td>
</tr>
<tr>
<td>Moscow region</td>
<td>4.8</td>
</tr>
<tr>
<td>Other regions of RF</td>
<td>20.4</td>
</tr>
</tbody>
</table>
more the fat mass, \( Z \) is positively related with active cell mass (ACM) in FFM (18). It may be assumed that these two measurements are the most objective, while further estimates of body compartments are derivatives of these measurements.

Data analysis included the standard statistical processing to obtain the main statistical parameters for characteristics under study. Besides, standardization procedure was used (Z-scores). Further intergroup comparisons were made with one-way ANOVA and multivariate discriminant analysis. All calculations were made using the software STATISTICA 6.0.

For all of the subjects, protocols of informed consent were signed prior to their examination.

RESULTS AND DISCUSSION

In Table 3, means and standard deviations for the main body dimensions in the three groups of boys aged from 14 to 17 are shown.

As can be seen from this table, differences in total body dimensions are practically negligible among the boys from different educational institutions at the age of 14; however, they increase to the maximal extent in all the parameters by the age of 17. This is also confirmed by ANOVA results presented in Table 4.

If the whole age range is taken into account (standardized values, or Z-scores) the SMS students are the shortest in stature and the biggest in BMI (Fig. 1).

There are a lot of differences in other body parameters in the three groups studied. In all linear dimensions, particularly in leg length, the SMS students are the shortest; the differences between the three groups are highly significant (Fig. 2). The same is true for body diameters: the SMS students are narrower in all the four diameters, while the students of sports school are much bigger in those (Fig. 3).

In arm circumferences, relaxed and contracted, (the latter is indicated as “Arm crcmf 2” in Fig. 4) the students from municipal schools have much lower values of both as well as those of forearm circumference. The SMS students take an average position, while young sportsmen, as can be predicted, are very much ahead of their counterparts (Fig. 4).

Analyzing skinfolds (Fig. 5) it is interesting to note that the group of young sportsmen (group 2) is clearly different from the other two groups in the distribution of skinfolds, having the lowest values of the skinfolds on the trunk and the highest on the extremities. In Fig. 6 the BIA results are given: bioimpedance characteristics (AR, \( Z_c \)) as well as the estimation of body mass components. Again, young sportsmen are clearly identified by their lower fat mass (FM) and higher active cell mass (ACM) and fat free mass (FFM). The range of the variation in the two latest parameters is really impressive: up to 0.6 standard deviation. This confirms the results of our previous studies (19). The SMS students have higher FM, as compared to the other two

### Table 3. Means (\( \bar{X} \)) and standard deviations (S) in the groups of boys under study

<table>
<thead>
<tr>
<th>Age</th>
<th>Stature (cm)</th>
<th>Body mass (kg)</th>
<th>Chest circumference (cm)</th>
<th>BMI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \bar{X} )</td>
<td>S</td>
<td>( \bar{X} )</td>
<td>S</td>
</tr>
<tr>
<td>Ordinary municipal school</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14-year-olds</td>
<td>166.2</td>
<td>6.9</td>
<td>55.5</td>
<td>10.5</td>
</tr>
<tr>
<td>15-year-olds</td>
<td>172.5</td>
<td>8.4</td>
<td>65.8</td>
<td>16.7</td>
</tr>
<tr>
<td>16-year-olds</td>
<td>175.2</td>
<td>5.9</td>
<td>64.3</td>
<td>12.3</td>
</tr>
<tr>
<td>17-year-olds</td>
<td>177.2</td>
<td>6.1</td>
<td>60.2</td>
<td>6.1</td>
</tr>
<tr>
<td>Sports school</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14-year-olds</td>
<td>167.4</td>
<td>10.3</td>
<td>59.7</td>
<td>14.9</td>
</tr>
<tr>
<td>15-year-olds</td>
<td>173.9</td>
<td>12.3</td>
<td>65.0</td>
<td>12.9</td>
</tr>
<tr>
<td>16-year-olds</td>
<td>176.9</td>
<td>11.5</td>
<td>67.2</td>
<td>16.9</td>
</tr>
<tr>
<td>17-year-olds</td>
<td>179.8</td>
<td>7.2</td>
<td>68.9</td>
<td>7.7</td>
</tr>
<tr>
<td>Suvorov Military School</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14-year-olds</td>
<td>166.6</td>
<td>7.0</td>
<td>58.7</td>
<td>8.2</td>
</tr>
<tr>
<td>15-year-olds</td>
<td>170.2</td>
<td>6.9</td>
<td>59.6</td>
<td>9.2</td>
</tr>
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<td>16-year-olds</td>
<td>172.5</td>
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</tr>
<tr>
<td>17-year-olds</td>
<td>175.3</td>
<td>6.4</td>
<td>69.7</td>
<td>12.5</td>
</tr>
</tbody>
</table>

### Table 4. ANOVA results (F-values) for the following characteristics in successive age groups of the boys under study

<table>
<thead>
<tr>
<th>Parameters</th>
<th>14-year-olds</th>
<th>15-year-olds</th>
<th>16-year-olds</th>
<th>17-year-olds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body length</td>
<td>1.92</td>
<td>2.63</td>
<td>1.39</td>
<td>6.46**</td>
</tr>
<tr>
<td>Body mass</td>
<td>0.19</td>
<td>1.77</td>
<td>3.56*</td>
<td>4.73**</td>
</tr>
<tr>
<td>Chest circumference</td>
<td>1.23</td>
<td>3.51*</td>
<td>0.92</td>
<td>3.56**</td>
</tr>
<tr>
<td>BMI</td>
<td>1.22</td>
<td>2.81</td>
<td>0.36</td>
<td>7.84***</td>
</tr>
</tbody>
</table>

* – \( p < 0.05 \), ** – \( p < 0.01 \), *** – \( p < 0.001 \).
Fig. 1. ANOVA results: total body dimensions in the three groups of boys (1 – ordinary municipal school; 2 – sports school; 3 – SMS)

Fig. 2. ANOVA results: linear body dimensions in the three groups of boys (1 – ordinary municipal school; 2 – sports school; 3 – SMS)
Fig. 3. ANOVA results: body diameters in the three groups of boys (1 – ordinary municipal school; 2 – sports school; 3 – SMS)

Fig. 4. ANOVA results: body circumferences in the three groups of boys (1 – ordinary municipal school; 2 – sports school; 3 – SMS)
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Fig. 5. ANOVA results: skinfolds in the three groups of boys (1 – ordinary municipal school; 2 – sports school; 3 – SMS)

- Forearm skf.
- Femur skf.
- Calf skf.

- Subscapular skf.
- Suprailiac skf.

extremities

0.5 0.4 0.3 0.2 0.1 0.0 -0.1 -0.2 -0.3 -0.4 -0.5 -0.6

0.5 0.4 0.3 0.2 0.1 0.0 -0.1 -0.2 -0.3 -0.4 -0.5 -0.6
groups (the differences are highly significant), and lower “active” components ACM and FFM.

Apart from being more brachimorphic, according to BMI values, the SMS students are also more brachcephalic. Comparison of the head index values in the three groups studied supports this statement. It can be clearly seen in Fig. 7 that the index values are significantly higher in the SMS group (p = 0.001).

In our previous works (20) it was shown that the changes in the head form can be considered as microevolutionary changes influenced by some social factors. In case of SMS students it might be the result of their sociodemographic differences in comparison to the students from the other two schools.

![ANOVA results: body composition parameters (bia) in the three groups of boys (1 – ordinary municipal school; 2 – sports school; 3 – SMS)](image1)

![Cephalic index in the three groups of boys (1 – ordinary municipal school; 2 – sports school; 3 – SMS)](image2)
Fig. 8. ANOVA results: functional traits in the three groups of boys (BPs – blood pressure systolic; BPd – blood pressure diastolic; HR – heart rate; HSr – hand strength right; HSI – hand strength left) (1 – ordinary municipal school; 2 – sports school; 3 – SMS)
In Fig. 8 ANOVA results for some physiological or “functional” parameters are given. The SMS students have the lowest values of blood pressure and heart rate. In hand strength they have higher values than the students of municipal school but lower values than young sportsmen.

Unfortunately, not much can be said about the process of sexual maturation in the groups at a given age range. However, we have calculated average scores for such a parameter as pubic hair, evaluated from 0 to 4 (15). As can be seen in Fig. 9, the students from groups 2 and 3 are maturing slower than ordinary Muscovites. This is particularly evident in the age groups of 15 and 16 years. At 17, boys in all the three groups in average still did not achieve their final adult status, score 4.

Next stage of the analysis suggested comparison of the groups using a complex of somatic and functional parameters. For this purpose step-by-step multivariate discriminant analysis was used. First, it was performed separately in each age group, and then for combined age groups. Table 5 shows the main results of multivariate comparisons: Wilks criterion – \( \lambda \), canonic correlation coefficient – \( R \), significance level – \( p \), and mean values of canonic variables.

As can be seen from Table 5, the differences between the studied groups of boys are highly reliable. Values of canonic variables decrease slightly in the combined group of 14–17-year-olds, which can be partly explained by the averaging effect.
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Fig. 10 shows that the groups practically do not transgress, and it appeared that only 10% of boys were mistakenly classified, which confirmed the high level of morphofunctional differentiation between the groups. This is particularly true for the students from the Suvorov Military School. As it was suggested above, specific patterns of the groups are determined not only by the differences in the boys' physical development level, but, to the greater extent, are related to the different social and demographic status of the groups.

CONCLUSIONS

Significant differences exist between the groups of children studying at SMS and other Moscow schools regarding the whole complex of morphological and functional parameters. Canonical analysis shows high degree of discrimination between the three groups studied.

The SMS students are more brachimorphic and brachicephalic. They have longer period of growth, show bigger annual increases in circumferences and weight, while in boys from municipal schools the values of these characteristics are decreasing, the trend typical of contemporary Muscovites.

The SMS students are characterized by the lowest values of functional parameters. They are also much stronger than ordinary Moscow boys.

Possible reasons for these differences are social and demographic factors, selection at enrolment, and specific living conditions of students inside the boarding school.

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