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Individual-typological assessment of the body fat component of the examined children and youth

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Abstract

Background. Individual anatomical variability in the human body shape can be characterized by its proportions, which serve as the main components of assessing the type of human constitution.

Aim. Establish individual typological features of the age-related changes in the fat component of the examined children, adolescents and youth.

Material and methods. 409 residents of the Smolensk region aged 4–20 years were examined: 212 males and 197 females. The cohort was divided according to the International Age Periodization 1965. Studies of the longitudinal-transverse type lasted for 10 years (2010–2020). The research methods included anthropometry, somatodiagnostics, determination of the biological development variant. To determine the fat component, the thickness of the skin-fat folds was measured, the calculation was made according to the formulas of Ya. Mateyko. The analyzed data had a normal distribution (Shapiro–Wilk test). The hypothesis of statistical significance of differences was tested using Student's t-test.

Results. Assessment of age-related changes in the body fat component of the subjects showed its continuous increase from 4 to 20 years. In female subjects it was higher, the significance of differences was established from the age of 12 ($p \leq 0.05$). The fat component had a high and moderate degree of correlation with body height and weight (r=0.533–0.753 and r=0.530–0.833), skin-fat folds (r=0.501–0.941) and body circumference (r=0.503–0.790). Significant differences were established between the extreme variants of biological development (isochronic approach) (t=2.305–2.604; $p \leq 0.05$). In the examined males, the difference was 10–12%, females — 25–30%. Somatotypological assessment (isosome approach) showed significant differences (t=3.462–6.781; $p \leq 0.001$) in the severity of fat mass in the subjects of both sexes of macrosomal and microsomal types.

Conclusion. The conducted studies have confirmed the presence of high individualization of the fat component's growth processes of male and female subjects of various somatic types and biological development variants.

Keywords: individual-typological assessment, fat mass, somatic type, biological development variant.

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Background

Excess fat mass in children, adolescents, and young adults has become a significant public health problem in the 21st century, according to the World Health Organization [1, 2]. Modern studies have reported differences in fat component expression within regions and between countries because of environmental, socioeconomic, and climatogeographic factors [3, 4]. The degree of fat mass manifestation reflects individual metabolic processes [5]. Childhood obesity increases the risk of cardiovascular diseases, musculoskeletal issues, and diabetes mellitus while negatively impacting the physical development and overall health of the younger generation [6–11].

The distribution and amount of body fat are genetically determined, and therefore, serve as a basis for individual typological assessment [12]. Understanding body composition from 4 years to 20 years can aid in tracking changes in fat mass over time and developing technologies to promote health and prevent noncommunicable diseases following the Strategy for Healthy Lifestyle, Prevention, and Control of Noncommunicable Diseases for the Period up to 2025 (Order No. 435n, July 10, 2015) [13]. Assessing individual body development characteristics is relevant during childhood, adolescence, and young adulthood, which can be achieved through the anthropometric approach [14–16].

This study aimed to determine the individual typological features of age-related changes in the fat component of children, adolescents, and young adults.

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Materials and methods

A total of 409 residents from the Smolensk Region, aged between 4 years and 20 years, underwent examination. Longitudinal and cross-sectional studies were conducted annually on three age groups, i.e., kindergarten-aged children (123 individuals), schoolchildren (139 individuals), and students (147 individuals). The number of subjects in each age group varied annually because some individuals were absent during the survey.

As of January 1, 2022, the Smolensk Region has a population of 909,856 people, with children, adolescents, and young adults accounting for approximately 20%. To ensure a confidence level of 95%, a sample size of at least 383 people is required. Therefore, the results obtained can be extrapolated to all individuals aged 4–20 years in the second decade of the 21st century who were born in the Smolensk Region.

Based on the 1965 International Age Periodization, the population is divided into four age periods, i.e., first childhood, second childhood, adolescence, and young adulthood. Longitudinal and cross-sectional studies were conducted at kindergartens and schools in the morning in the presence of a medical professional. The locations included Kindergarten No. 7 in Yartsevo, Kindergarten for Children with Musculoskeletal Disorders in Smolensk, and Secondary School No. 10 in Yartsevo. Studies were also conducted in the Laboratory of the Department of Anatomy and Biomechanics at the Smolensk State University of Sports. This study was conducted for 10 years (2010–2020) and included participants from the first and second health groups. Written consent was obtained from the children and their parents.

Skinfold thickness was measured using a caliper in millimeters, longitudinal dimensions were assessed with a Martin anthropometer in centimeters, body weight was measured using a Tanita BC-601 scale (Tanita, Japan) in kilograms, and girth dimensions were measured with a plastic measuring tape in centimeters. This study followed the generally accepted rules of anthropometric data collection [17, 18].

The following formula for calculating growth intensity was used to compare indicators with varying units of measurement:

$$\text{GI} = \frac{l_2 - l_1}{0{,}5 \times (l_2 + l_1)} \times 100\%,$$

where GI is the growth intensity, l_1 is the result of the initial measurement, and l_2 is the result of repeated measurement [19].

The three-level metric method of somatotyping is an objective approach developed to assess the body type of children, adolescents, and young adults during mass medical examinations and prognostic and confirmatory sports selection [20, 21]. This method enables the estimation of the body's component composition. The fat component was determined by measuring the skinfold thickness of the human body, and absolute and relative values were calculated using the formulas derived by Matejko [19].

In recent years, the practice of determining organism maturity through anthropometric data, also known as the biological developmental variant (BDV), has become increasingly common [13, 19]. The calculation is performed using the following formula:

$$\text{BDV} = \frac{\text{BW}/[(\text{UAC} \times 0{,}5\text{ULL}) + (\text{UTC} \times 0{,}5\text{LLL})]}{\text{BL}/[(\text{CIRC}_{\text{shoulder}} + \text{CIRC}_{\text{pelvic}}) \times 0{,}5\text{H}\textit{trunk}]} - \text{C/D},$$

where BW is the body weight, UAC is the upper arm circumference, AL is the arm length, UTC is the upper thigh circumference, LLL is the lower limb length, BL is the body length, $\text{CIRC}_{\text{shoulder}}$ is the shoulder circumference, $\text{CIRC}_{\text{pelvic}}$ is the pelvic circumference, H_{trunk} is the trunk height, and *C* and *D* are tabulated data [19].

Three BDVs are distinguished for children, adolescents, and young adults depending on the length of the growth period, i.e., 0.000–0.432 for retardation and stretched BDV (C BDV), 0.433–0.568 for normal and trivial BDV (B BDV), and 0.568–1.000 for shortened BDV (A BDV) [13].

Modern methods of mathematical statistics were used to determine the reliability and validity of the obtained results. The relationships among the investigated indicators were assessed using computer programs, such as Statistica 6.0, Somatodiagnostica_1.07, Microsoft Word, Microsoft Excel, and SPSS.

The analysis showed a normal distribution (Shapiro–Wilk test) [22]. The calculated parameters include the statistical mean (*M*), standard deviation (σ), coefficient of variation, arithmetic mean error ($\pm m$), growth intensity (%), average annual growth (in absolute and relative values), and correlation coefficient (r). The hypothesis of statistical significance of differences was tested using Student's *t* test [22, 23].

Results and discussion

This study examined age-related changes in the fat component of female and male subjects aged 4–20 years. Results showed a 19% increase in body weight for females (from 2.190 kg to 12.670 kg) and a 16% increase in body weight for males (from 2.130 kg to 10.590 kg). These findings are consistent with the data reported by Smolyakova who observed an increase in the fat mass of schoolgirls by 8 kg 100 g [16].

Table 1 shows significant differences in the expression of the fat component during the first and second growth spurts. These findings are consistent with those reported by Khrisanfova [19].

The percentage of body fat in humans changes unevenly with age. In female subjects, the range of fluctuations was between 13.27% and 25.93% of body weight (2.75 and 13.79 kg), and in males, it ranged from 12.39% to 20.66% (3.18 and 8.68 kg; refer to Table 1).

Based on the data from the 1990s, the fat mass of 20-year-old females accounted for 27.7% of their total body weight, whereas it was only 13% to 15% in males of the same age. A study conducted over 25 years detected a decrease in relative fat content in females ($t = 2.326$; $p \leq 0.05$), whereas it remained unchanged in males ($t = 0.648$, $p \geq 0.05$) [16].

Foreign studies have also reported gender differences in fat mass indicators and their rate of increase [24]. Silva, Baxter-Jones, and Maia reported an increase in the proportion of fat in females aged 8–16 years by 8.32% (from 15.94% to 24.26%) and a decrease in males by 2.5% with age (from 13.40% to 10.98%) [3]. Laurson, Eisenmann, and Welk reported that American girls aged 8 years had a fat mass of 17.9%, whereas boys had 15.5% [25]. According to the results of the examination of Turkish children conducted by Cicek et al. [26], the fat component of 8-year-old girls and boys was 18.1% and 17.6%, respectively. The data from McCarthy and Plachta-Danielzik et al. [4, 27] showed that 8-year-old girls in England and Germany had a fat percentage of 24.1%, whereas boys had 19.5%.

Fat mass in children and adolescents is the result of complex growth and development processes, particularly during sensitive periods [3]. When conducting comparative assessments of different populations, factors, such as socioeconomic level and ethnicity, need to be considered [3].

A comparison of fat composition in Russian and foreign subjects aged 4–20 years showed that modern Russian girls and young women have a lower relative fat content than their foreign counterparts. The highest fat content was observed in English and German girls. At the age of 8 years, the difference was 10.4%. According to Silva et al. [3], boys and young men have the lowest relative fat content. The highest values were observed in English and German children by McCarthy et al. [4, 27], with a value of 8.5%. Table 1 shows that modern Russian boys and young men have average values of fat component expression.

According to previous research, the number of fat cells is genetically predetermined, with males having a 78% predisposition and females having a 53% predisposition. The extent of the increase in fat cells is strongly influenced by lifestyle, living conditions, and physical activity [16, 19].

Table 1. Age-related changes in the fat mass of subjects aged 4–20 years

Age, years	Number, females/males	Absolute fat mass, kg		p
		Females	Males	
4	50/60	2,19	2,13	≥0,05
5	50/63	2,5	2,48	≥0,05
6	50/65	2,75	2,75	≥0,05
7	51/64	3,27	3,18	≥0,05
8	57/65	3,85	4,23	≥0,05
9	65/58	4,85	5,97	≤0,001
10	66/63	6,49	6,63	≥0,05
11	63/65	7,73	8,19	≥0,05
12	63/66	9,77	8,68	≤0,05
13	64/63	10,79	8,74	≤0,001
14	65/65	11,43	9,47	≤0,001
15	60/66	13,79	10,11	≤0,001
16	63/64	13,9	8,78	≤0,001
17	69/68	11,77	9,57	≤0,001
18	68/63	10,8	10,3	≥0,05
19	66/66	12,25	10,54	≤0,01
20	72/67	12,67	10,59	≤0,001

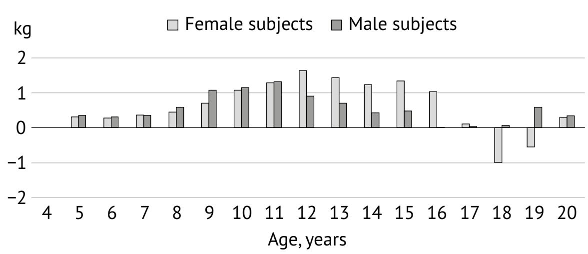

Fig. 1. Age changes in fat mass gain of subjects aged 4–20 years

The dynamics of age-related changes in the fat component can be assessed by calculating its increase indicators. In both male and female subjects, a similar tendency to increase until the age of 11 years was observed (see Fig. 1). Significant differences begin to appear from the age of 12 years when girls reach puberty ($p \leq 0.05$–0.001; see Table 1). Gender differences in children were identified by Zernova as early as the first year of life [16]. Khrisanfova reported an increase in sexual dimorphism as a sign of pubertal development [19]. A high fat content in female subjects is a prognostic indicator of earlier puberty [19].

A comparison of the growth rates of morphometric parameters in male and female subjects

Table 2. Comparison of age-related changes in the intensity of increase in height, body weight, and fat mass of female (F) and male (M) subjects aged 4–20 years (%)

Age, years	*n*, F/M	Height		p	*n*, F/M	Body weight		p	*n*, F/M	Fat mass		p
		F	M			F	M			F	M	
5	51/66	4,28	6,49	≥0,05	50/64	16,38	13,44	≥0,05	50/63	13,22	15,18	≤0,001
6	52/66	10,07	9,00	≥0,05	50/66	16,10	15,83	≥0,05	50/65	9,52	10,32	≤0,001
7	52/64	5,43	7,99	≥0,05	51/64	13,03	17,48	≥0,05	51/64	17,27	14,50	≤0,001
8	66/66	5,70	2,96	≥0,05	66/65	12,09	7,69	≥0,05	57/65	16,29	28,34	≤0,001
9	66/66	5,46	6,21	≥0,05	65/65	11,12	20,79	≤0,01	65/58	22,99	34,11	≤0,001
10	67/64	5,39	2,88	≥0,05	66/63	13,13	0,21	0,001	66/63	28,92	10,48	≤0,001
11	65/65	2,01	2,77	≥0,05	65/65	4,86	10,85	≤0,01	63/65	17,44	21,05	≤0,001
12	66/66	5,41	3,75	≥0,05	63/66	12,32	10,74	≥0,05	63/66	23,31	5,81	≤0,001
13	64/61	0,78	1,05	≥0,05	64/63	8,51	0,24	≤0,001	64/63	9,92	0,69	≤0,001
14	65/65	2,42	4,08	≥0,05	66/65	9,30	9,46	≥0,05	65/65	5,76	8,02	≤0,001
15	62/66	1,81	3,74	≥0,05	62/66	12,40	15,11	≥0,05	60/66	18,71	6,54	≤0,001
16	63/64	0,19	2,55	≥0,05	65/64	1,80	4,34	≥0,05	63/64	0,79	–14,08	≤0,001
17	69/68	1,41	3,06	≥0,05	70/69	6,59	22,88	≤0,05	69/68	–16,60	8,61	≤0,001
18	70/63	1,27	0,45	≥0,05	70/69	1,66	3,18	≥0,05	68/63	–8,60	7,35	≤0,05
19	67/69	0,90	0,40	≥0,05	69/67	0,69	0,54	≥0,05	66/66	12,58	2,30	≤0,001
20	72/70	–0,12	0,23	≥0,05	72/68	–1,30	1,08	≥0,05	72/67	3,37	0,47	≤0,001

Note: *n* is the number of female and male subjects.

showed nonsimultaneous increases with age. This study determined that the most intensive growth rates occurred in girls aged 5–6 years (10.07%) and in boys aged 5–7 years (7.99% to 9.00%). Body weight showed the highest increase in girls aged 4–10 and 11–15 years (11.12% to 16.38% and 8.51% to 12.40%, respectively) and in boys aged 4–9, 14–15, and 16–17 years (7.69% to 20.79%, 15.11%, and 22.88%, respectively). Fat mass increased the most in girls aged 6–12, 14–15, and 16–17 years (16.29% to 28.92%, 18.71%, and 16.6%, respectively) and in boys aged 7–11 and 15–16 years (10.48% to 28.34% and 14.08%, respectively; Table 2). As shown in Table 2, growth has the lowest rate of increase, whereas the fat component has the highest rate of increase. The intensity of live weight increase lags behind the rate of body weight increase by 1.0–2.5 years. The subjects reached mature height at 17–18 years of age and mature body weight at 18–19 years of age. Fat mass indicators stabilized by 16–17 years of age.

According to Dorokhov, fat cell growth undergoes a significant slowdown at 15–16 years of age and nearly completely ceases at 18–20 years of age. After the age of 20 years, cell hyperplasia stops and transitions to hypertrophy [16].

The homogeneity of the group can be assessed by the magnitude of variation in the trait. Studies have shown that the coefficient of variation of the fat component in children during the first period and the beginning of the second period of childhood did not exceed 20%. However, at the end of the second period of childhood, the coefficient of variation of the fat component reached the maximum value, i.e., up to 35%, with a subsequent decrease in adolescence. The high discordance in fat mass indices during puberty is attributed to the increased influence of socioenvironmental factors and varying levels of physical activity.

As the child's body matures, changes in the distribution of body fat topography occur [19].

The correlation analysis data showed high and moderate degrees of linear dependence between fat mass and the following indicators in female subjects:

– Body weight at 4–5 years old (r = 0.622–0.704), 7–8 years old (r = 0.706–0.715), and 12–16 years old (r = 0.622–0.760);

– Height at 4–5 years old (r = 0.690–0.753) and 8–9 years old (r = 0.633–0.724);

– Skinfolds at 4–20 years old (r = 0.516–0.879);

– Minimum lower arm circumference at 8 years old (r = 0.535) and maximum lower arm circumference at 17 years old (r = 0.550);

– Upper arm circumference at 17–18 years old (r = 0.538–0.555);

– Chest circumference at 8 years old (r = 0.598);

– Upper thigh circumference at 17–20 years old

($r = 0.564–0.604$) and lower thigh circumference at 17 years old ($r = 0.612$);

– Maximum tibia circumference at 17 years old ($r = 0.542$);

– Waist and pelvic circumference at 20 years old ($r = 0.668$ and $r = 0.600$, respectively).

A linear correlation between the fat component and the following parameters was observed in males:

– Body weight at 4–5 years old ($r = 0.530–0.534$), 9–13 years old ($r = 0.595–0.833$), and 17–20 years old ($r = 0.589–0.731$);

– Height at 4–5 years old ($r = 0.533–0.698$);

– Skinfolds at 4–20 years old ($r = 0.501–0.941$).

From 8 years to 13 years, a correlation between body circumferences ($r = 0.503–0.790$) was observed. Lower arm width showed a correlation from 8 years to 10 years ($r = 0.533–0.619$), whereas thigh width showed a correlation at 9 and 17–18 years ($r = 0.548$ and $r = 0.529–0.539$, respectively).

The correlation analysis showed a clear relationship between the size of skinfolds and other anthropometric indices in children, adolescents, and young adults, indicating fat accumulation and growth processes. This finding is consistent with the results reported by Kolodko [19].

The correlation indices were observed to be stronger in male subjects than in female subjects, which is associated with a lower variability of fat expression in male subjects than in female subjects.

According to Tanner, the trunk area of girls and young women, particularly in skinfolds located to the right and above the navel, at the axilla, and at the lower corner of the scapula, has a high degree of fat expression. By contrast, this type of fat expression is practically absent in boys and young men [28].

The data indicated that the dynamics of fat mass should only be considered when taking into account the BDV (isochronous approach), as the coefficient of variation decreases by two to three times.

The results of this study indicated that both male and female subjects with the accelerated development variant (A BDV) have the highest fat mass values, whereas those with the stretched variant (C BDV) have the lowest fat mass values [16]. The most significant differences were observed between extreme BDVs during the pubertal period ($t = 2.305–2.604$; $p \leq 0.05$). In male subjects, the difference reached 10% to 12% (2.8 kg). By contrast, in female subjects, the difference reached 25% to 30% (4.5 kg).

The evaluation of fat expression in subjects with different BDVs during the 1990s showed that, in males, the variant differences of A BDV and C BDV were 4% to 5%, whereas in females, the variant differences of A BDV and C BDV were more than 8%. These values are 2.4–3.5 times lower than those observed in modern children, adolescents, and young adults [19].

A comparison of fat mass gain intensity was conducted among individuals with different developmental variants. The results showed that each variant has a strictly limited zone of gain, which can be used to determine the variant of the subjects in a particular population. The zone of unpredictability occurs between the ages of 10 and 12 years when the intensity of growth is the same for all developmental variants. This period coincides with the onset and height of puberty in the female subjects. After the transition to the period of maturity, the rate of fat mass gain becomes indistinguishable once again [16].

According to Ashina et al. [29], the severity of skinfolds in children is influenced by the level of biological development achieved and determined by the constitutional features of the body type.

This study examined the distribution of fat mass by somatic type (isosomatic approach) in male subjects aged 4–20 years. The results showed a relatively uniform distribution of somatic types with a predominance of the mesosomatic type and two transitional types, i.e., micromesosomatic and mesomacrosomatic. However, at 10–15 years of age, the proportion of micromesosomatic-type children increased. Moreover, at 16–20 years of age, the number of subjects in the micromesosomatic and mesomacrosomatic types began to increase.

Based on the fat component expression, most female subjects (up to 18 years old) were classified as mesosomatic type. However, from the age of 19 years, the proportion of mesomacrosomatic types increased, resulting in increased fat deposition in girls.

Between the ages of 4 and 20 years, mesosomatic type male subjects experienced an increase in fat mass of 8.18 kg, whereas macrosomatic type male subjects experienced an increase in fat mass of 13.3 kg and microsomatic type male subjects experienced an increase in fat mass of 4.12 kg. During puberty, boys had the highest relative content of fat, with microsomatic types having 14.9% body mass, mesosomatic types having 20.6% body mass, and macrosomatic types having 28.3% body mass. The lowest percentage of fat mass in boys was observed at 6–8 years of age, with 2.4 kg or 8.3% body weight.

The fat mass of female subjects between the ages of 4 and 20 years increased as follows: in the mesosomatic type, by 10.5 kg; in the microsomatic type, by 6.5 kg; and in the macrosomatic type, by 14.5 kg. The highest values were also observed in the macrosomatic type. The relative content of fat mass reaches its maximum at 12–15 years of age, accounting for 33.9% of body weight. The minimum values were observed at the end of the first period and the beginning of the second period of childhood, accounting for 2.4 kg or 10.6% of body weight.

Significant differences (t = 3.462–6.781; $p \leq 0.001$) in the expression of fat mass between extreme body types (i.e., microsomatic and macrosomatic) in both male and female subjects were detected.

The results of this study indicated that female subjects reach the maximum fat component later than male subjects by a difference of 2 years. Furthermore, by the age of 20 years, girls express 1.5 times more fat mass than boys.

Representatives of different body types differ in fat mass during childhood and adolescence and have varying tendencies to increase fat mass. These differences determine the individual typological status of the subjects [16].

Conclusions

This study has confirmed that the growth processes of the fat component in male and female subjects of different somatic types and variants of biological development are highly individualized. Therefore, an individual typological assessment of modern children, adolescents, and young adults, considering the principles of isonomy and isochrony, needs to be conducted. This approach is justified and demanded in current times.

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