

# Substantiation of the methodology for assessing the biological age of adolescents

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## ABSTRACT


**Aim:** To substantiate the methodology for assessing the biological age of adolescent high schoolers (boys and girls).

**Materials and Methods:** Boys aged 14-15 (n = 102) and girls aged 12-13 (n = 101) were studied. The choice of these age groups is explained by the presence of the most significant individual differences in morphological and functional characteristics in these adolescents. Methods: anthropometry, somatometry, somatoscopy, tonometry, spirometry, dynamometry, Stange's test, Rufier and Robinson indices. The interaction of the results of different methods of assessing biological age was conducted on one sex-age sample using factor analysis (principal components method).

**Results:** It has been established that the biological age of adolescents can be reliably determined using a set of three components: an assessment of the level of physical development, the index of heterochronicity, and the degree of manifestation of secondary sexual characteristics (for boys with a probability of 90.2%, for girls – 92.1%). The percentage ratio of these components has sexual peculiarities. Methodologies for assessing biological age for scientific purposes and rapid assessment for use in the practice of physical education and sports have been proposed. The indicators of rapid assessment are body length and the degree of hair development in the axilla. The reliability of the rapid assessment is 81.4% for boys and 83.2% for girls.

**Conclusions:** Developing adequate physical activities for adolescents of different biological ages will help improve the physical health of the younger generation.

**KEY WORDS:** adolescents, biological age, methodology, rapid assessment

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## INTRODUCTION

One of the modern ways to improve high schoolers' physical health is to use a differentiated approach in physical education training sessions as an important condition for teaching and upbringing. It is important to implement this direction for adolescents because of significant individual differences in morphofunctional indicators in people of the same class and gender. This is especially true for 14-15-years old boys and 12-13-years old girls [1, 2].

It is established that adolescents' organism formation is characterized by heterochronism, extreme degrees of which are expressed either in acceleration of development or in slowing down against average values, characteristic for a given chronological age [1, 3]. Knowledge about heterochronicity helped identify the "biological age" as the formation of morphological structures and related functional manifestations of the organism's vi-

tal activity, characteristic of a given chronological age, achieved by an individual [2-4].

Many authors emphasize the significant differences between biological and chronological age [4, 5]. As of today, it has been proven, for example, that girls of the same chronological age differ in the pace of biological development. The difference in the rate of formation of secondary sexual characteristics can be 1-1.5 years [3, 5]. It has been established [4, 6] that among girls aged 12-13 years, 48% have a biological age that corresponds to the chronological age, 19% are ahead, and 33% are behind. The physical health assessment revealed that 38% of girls aged 12-13 with low and below-average levels are female high schoolers whose biological age is ahead of their chronological age [4, 5, 7]. It is noted that the value of somatometric and physiometric indicators, circulatory and external respiratory functions features, cardiac performance, and blood distribution system in

large and small circles are more interdependent with adolescents' biological age than chronological age. The smallest dispersion of somatic parameters occurs in preschool age and reaches an average of one and a half years, and the largest – 3-4 years – is observed in adolescents [4, 8, 9].

The heterochronic nature of adolescents' biological development is also the reason for significant variability in the manifestation of their physical abilities indicators. Thus, in 12-13-years-old female high schoolers [3, 10] individual values of endurance, according to the results of 6-minute running at a distance, are in the range of 1060-1400 meters, the strength of hand muscles – in the range of 14-27 kg, strength endurance (lifting the torso from the supine position in 30 seconds) – 16-25 times, speed (according to the results of running 20 meters on the run) – in the range of 1.2-1.8 seconds, speed and strength capabilities (throwing a ball) – 290-380 cm. The given values have significantly substantial differences. The same is observed in indicators of agility, where the intragroup variation of results is 7-20 % and is the largest at 12-13 years old [2, 6]. It has also been proved that different values of total body size significantly influence the manifestation of physical abilities of adolescents [8, 11]. Thus, among 12-15-years-old high schoolers almost 75 % of variations of speed and strength abilities are caused by indicators of body weight and length as well as age, and the partial contribution of the latter does not exceed 25 % [1, 5, 12]. Thus, according to scientists, high schoolers of the same grade and sex are not a homogeneous group in terms of morphological and functional state, since the age-related process of growth and development of the high schoolers' organism is characterized by significant individual differences, most of all in adolescents. Among the reasons for the differences may be heredity (different rates of biological development of the body) and the influence of environmental conditions (different motor activity).

Studying the differences between the chronological and biological ages of high schoolers is important not only from a theoretical point of view but also for working out adequate developmental and health-improving activities in the process of physical education. Currently, this problem is still in its infancy. The main obstacle to its solution is a large number of proposals for assessing the biological age of high schoolers: 9 methodologies for boys and 14 for girls [13, 14, 15, 16]. The indicators and their combinations, as well as approaches and methods, are offered in different ways. To find out which of them should be preferred to work out developmental and health-improving physical education training sessions based on the chosen one, the interaction of the above proposals was studied separately for adolescent girls and boys.

## AIM

The aim of this article is to substantiate the methodology for assessing the biological age of adolescent high schoolers (boys and girls).

## MATERIALS AND METHODS

The research involved boys aged 14-15 (n = 102) and girls aged 12-13 (n = 101). The choice of these age groups is explained by the presence of the most significant individual differences in morphological and functional characteristics in these adolescents.

Methods: theoretical – analysis and generalization of literary sources, systematization, comparison of different views on the problem under research; empirical – anthropometry, somatometry, somatoscopy, tonometry, spirometry, dynamometry, Stange's test, Ruffier, Robinson indices; data processing methods – sampling method, correlation and factor analysis.

To assess the biological age of adolescents, the following indicators were proposed: absolute and relative values of total body size, degree of maturity of secondary sexual characteristics, type of physical development, puberty rate, physical condition, type of somatic status, physical development index, annual growth of body length, degree of sexual maturity, age standards of lung capacity and muscle strength, somatotype, the index of heterochronicity, and comprehensive assessment of physical development. The interaction of the results of these indicators was determined using factor analysis. The task of factor analysis was the transition from numerical indicators of a certain system to a relatively small number of hidden factors [5]. After statistical processing, three representative indicators were identified: the level of physical development, the index of heterochronicity of growth and development, and the degree of manifestation of secondary sexual characteristics. The level of physical development was assessed by the ratio of the main body dimensions (body weight, body length, and chest circumference). The Index of Heterochronicity (IH) was calculated using the formula:  $IH = ((l - p) \cdot l) / ((L - P) \cdot L) \cdot (T / t) \cdot 100$ , where: L – body length, cm; P – body weight, kg; T – chest circumference, cm; l, p, t – relevant individual indicators.

The degree of manifestation of secondary sexual characteristics was assessed by the indicators of axilla and pubic hair, mammary gland development, and menstruation in girls (on a 3-point scale) [1, 6].

The procedure for organizing the research was previously agreed with the Committee on compliance with Academic Integrity and Ethics of the Ukrainian State Dragomanov University. This research followed the regulations of the World Medical Association Declaration of Helsinki and ethical principles for medical research

**Table 1.** Scheme for assessing the biological age of adolescent boys, recommended for use for scientific purposes

Level of physical development	Index of Heterochronicity		
	94 and less	95-110	111 and more
Below-average, low	P	C	A
Average	C	C	C
High, above-average	P	C	A
Gender formula	$A_0P_{0'} A_0P_{1'} A_1P_0$	$A_{1-2}P_{2'} A_2P_{1-2'} A_1P_1$	$A_{2-3}P_{3'} A_3P_{2-3}$

Note: C – biological age corresponding to chronological age; A – accelerator; P – retardant;  $A_{0-3}$  – degree of hairiness in the axilla;  $P_{0-3}$  – degree of hairiness on the pubis.

**Table 2.** Scheme for rapid assessment of the biological age of adolescent boys, recommended for use in the process of physical education

Body length	Level of hair development in the axilla		
	0-1	2	3
Low, below-average from ( $X - 0.68 \sigma$ and less)	P	P	C
Average ( $X \pm 0.67 \sigma$ )	C	C	C
Above-average, high ( $X + 0.68 \sigma$ and more)	C	A	A

Note: C – biological age corresponding to chronological age; A – accelerator; P – retardant.

**Table 3.** Scheme for assessing the biological age of 12-13-years-old girls, recommended for use for scientific purposes

Level of physical development	Index of Heterochronicity		
	94 and less	95 – 100	111 and more
Low, below-average	P	C	A
Average	C	C	C
Above-average, high	P	C	A
Gender formula	$A_0P_{0'} A_0P_{1'} A_1P_0$	$A_{1-2}P_{2'} A_2P_{1-2'} A_1P_1$	$A_{2-3}P_{3'} A_3P_{2-3}$

Note: C – biological age corresponding to chronological age; A – accelerator; P – retardant;  $A_{0-3}$  – degree of hairiness in the axilla;  $P_{0-3}$  – degree of hairiness on the pubis.

**Table 4.** Scheme for rapid assessment of the biological age of 12-13-years-old girls

Body length	Degree of hair development		
	0 – 1	2	3
Low, below-average from ( $X - 0.68 \sigma$ and less)	P	P	C
Average ( $X \pm 0.67 \sigma$ )	C	C	C
Above-average, high ( $X + 0.68 \sigma$ and more)	C	A	A

Note: C – biological age corresponding to chronological age; A – accelerator; P – retardant.

involving human subjects. Prior consent to participate in the research was obtained from all the participants.

## RESULTS

### SUBSTANTIATION OF THE METHODOLOGY FOR ASSESSING THE BIOLOGICAL AGE OF ADOLESCENT BOYS

As a result of factorization of the matrix of intercorrelations of nine complex indicators for assessing the biological age of boys, three significant independent factors were identified: the level of physical development, the index of heterochronicity of growth and development, and the degree of manifestation of secondary sexual characteristics. The total

contribution of these factors to the generalized variance of the sample was 90.2 %. The contribution of the first factor (the level of physical development), the main features of which are the value of total body size, physiometric indicators, and components of body weight, amounted to 58.5 % of the total variance of the sample. The contribution of the second factor (the index of heterochronicity of growth and development) to the generalized variance of the sample was 18.9 %, and the contribution of the third factor (the degree of manifestation of secondary sexual characteristics) was 12.8 %. The contribution of the remaining factors to the generalized variance of biological age estimation was statistically insignificant (less than 5 %).

Based on the results of factor analysis the scheme of complex determination of adolescent boys' biological

age was developed, recommended for use for scientific purposes (Table 1), and its rapid assessment – for application in the practice of physical training (Table 2).

### SUBSTANTIATION OF THE METHODOLOGY FOR ASSESSING THE BIOLOGICAL AGE OF ADOLESCENT GIRLS

Unlike boys, 14 methodologies are proposed in the literature to assess adolescent girls' biological age, not 9. Therefore, in the case of female high schoolers, there is also a problem of finding the most informative methodology. To this end, we studied the relationship between the methodologies on one sample (101 girls aged 12-13) using factor analysis. The first factor – the level of physical development (proportion of 43.5 %) – characterizes the values of total body size and physiometric indicators. The second factor – the index of heterochronicity of growth and development – is associated with indicators of somatic body type (contribution to the generalized variance – 26.3 %). The third factor is the degree of manifestation of secondary sexual characteristics (contribution – 22.3 %). The contribution of other factors to the generalized variance of biological age assessment was statistically insignificant (7.9 %). The proportion of each factor was determined by factor analysis, namely, the sum of the squares of the correlation coefficients was divided by the total number of biological age estimation methodologies (by 14). The total contribution of these factors to the total variance of the sample of adolescent girls was 92.1 %. In total, these indicators in girls determine biological age more reliably (by 1.9 %) than in boys, and the proportion of each of them has specific differences.

Based on these indicators, the methodology for assessing the biological age of adolescent girls aged 12-13 years was developed, recommended for use for scientific purposes (Table 3), and a rapid assessment for use in physical education practice (Table 4). If two out of three indicators (the level of physical development, the index of heterochronicity, and gender formula) correspond to middle-aged values, then biological age corresponds to chronological age. If two of the three fall within the range of low or high values, they respectively characterize slowed or accelerated rates of biological development (retardant or accelerator)

To determine the biological age of adolescent girls at school, a rapid assessment is proposed, which allows teachers and high schoolers to quickly determine the pace of biological development: slow (P), medium (C), and accelerated (A) relative to the chronological age of female high schoolers.

The rapid assessment includes two indicators: body

length and the degree of development of axilla hair. The body length score (low, below-average, average, above-average, high) is determined by regional standards for assessing high schoolers' physical development.

The assessment of the degree of development of hair in the axilla is determined by a three-point system, namely: 0 – no hair, 1 – separate hairs, 2 – the presence of hair in the form of a mustache, 3 – hair developed over the entire surface of the axilla. According to the factor analysis, the total efficiency of this methodology in determining the biological age of 12-13-years-old adolescent girls is 83.2 %.

### DISCUSSION

For many decades, scientists from around the world [3, 4, 13, 17] have been studying the issue of assessing a person's biological age, but there are still no uniform criteria for determining it. There are also no uniform criteria for determining the biological age of high schoolers. The concept of "biological age" arose because of the general need to consolidate a large amount of data on individual characteristics of ontogenesis in periods corresponding to chronological age. That is why it pays tribute to the significant individual variety of organismal characteristics that are somehow related to the function of time, especially during periods of growth and development [4, 15]. Depending on the tests used, biological age can be assessed in the coordinates of any body system and at virtually all stages of ontogeny [16, 17]. Foreign scientists have made a significant contribution to the development of determining the biological age of children and adolescents [13, 14, 16, 18, 19]. The authors of [16] based their methodology on a scoring system for the manifestation of each of the proposed signs of biological development of the subjects. Geneticists at Morgantown University (West Virginia) have proposed a fundamentally new methodology for determining a person's biological age. For this purpose, only one indicator is measured. The methodology is as follows: using a blunt spatula, a sample of mucosal cells is taken from the inner surface of the cheek. Scientists believe that changes in the energy state of cells correspond to age-related changes in the body as a whole [19-21]. It is still an open question how convenient this methodology is. After all, it requires special equipment and the professionalism of researchers. It is unlikely to be widely used as a rapid methodology by teachers of secondary schools.

The analysis of modern sources on this issue shows that morphological [17], functional [18], and complex [19, 22] criteria are proposed to determine the

biological age of adolescents. Determining the most valid among them is of great theoretical and practical importance in modern conditions.

## CONCLUSIONS

1. As a result of factorization of the matrix of intercorrelations of nine complex indicators of biological age assessment of 14-15-years-old boys, three significant independent factors were identified: the level of physical development (58.5 % of the total variance of the sample), the index of heterochronicity of growth and development (with a proportion of 18.9 %) and the degree of manifestation of secondary sexual characteristics (with a proportion of 12.8 %). The total contribution of these factors to the generalized variance of the sample was 90.2 %.
  2. Unlike boys, fourteen methodologies were proposed to assess the biological age of adolescent girls, not nine. The biological age of adolescent girls can also be reliably (with a probability of 92.1 %) determined using three indicators: the level of physical development, the index of heterochronicity of growth and development, and the degree of manifestation of secondary sexual characteristics with a proportion of 43.5 %, 26.3 %, and 22.3 %, respectively.
  3. Based on these indicators, methodologies for assessing the biological age of boys and girls in primary school have been developed, which are recommended for use both for scientific purposes and for rapid assessment for use in physical education practice.
- Prospects for further research include the development of differentiated physical activity during physical education training sessions for primary school-aged children.

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### CONFLICT OF INTEREST

The Authors declare no conflict of interest

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