Somatometric Method to Assess the Level of High Schoolers' Physical Development

Somatometryczna metoda oceny poziomu rozwoju fizycznego uczniów szkół średnich

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SUMMARY

Aim: To develop tables to assess the physical development of high schoolers based on the interaction of total physical dimensions.

Materials and Methods: To achieve this goal, we studied the indicators of body length, body weight and chest circumference of 7-17 years old boys (n=1111) and girls (n=1133) of secondary schools in Kyiv (Ukraine). Multiple correlation was used to calculate the interaction of indicators of total physical dimensions, and multiple regression was used to develop gender and age standards of physical development of high schoolers.

Results: The tables to assess physical development of high schoolers of a certain gender and age have been developed. The tables contain body length in vertical direction and body weight or chest circumference in horizontal direction, depending on what is needed for determination: the proper values of CC or body weight. The quantitative characteristics of high schoolers with good, excessive, below average and low levels of physical development are presented.

Conclusions: Rational organization of physical training of high schoolers is impossible without objective testing of the level of their physical development. Timely corresponding testing is a guarantee in preventing physical strains and health problems.

Key words: physical development, health, high schoolers

Słowa kluczowe: rozwój fizyczny, zdrowie, uczniowie szkół średnich

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INTRODUCTION

The study of physical well-being of high schoolers, and even more so, the methods of its optimization is of great theoretical and practical importance. Along with the level of functioning of body systems, the physical development of a human being is one of the main indicators of physical well-being, which is characterized by a complex of somatometric and somatoscopic features [1-3].

The level of physical development plays a special role in determining the health status of high schoolers, whose body is in the process of formation and due to its plasticity is extremely prone to both positive and negative influences of environmental factors. Therefore, the indicators of physical development reflect not only the health status of children and adolescents, but also the socio-economic and socio-hygienic conditions of their lives, the level and quality of organization and methods of teaching physical education in secondary school [4, 5].

The physical development of high schoolers was studied from 1925, in stages: 1925-1927, 1937-1938, 1947-1949, 1955, 1959-1960, 1966-1967, 1970-1971 and, finally, in 1969-1973 [6]. Forasmuch as, the tables for assessing the physical development of high schoolers, developed in 1974 on the basis of research of 1969-1973, are outdated not only in time but also for calculation methods, there is an urgent need to develop new tables for assessing the physical development of high schoolers, which could be recommended as criteria for individual and group assessment.

AIM

The aim of this article is to develop tables to assess the physical development of high schoolers based on the interaction of total physical dimensions.

MATERIALS AND METHODS

A special difference of our method is the development of tables for assessing the proper values of body weight not only in relation to body length (as it was used previously), but also taking into account the actual values of chest circumference (CC). Accordingly, assessment tables of proper CC indicators were developed taking into account the combined effect of body length and weight indicators. Multiple correlation and regression were used for this purpose.

The comparative data of pair and multiple correlation coefficients became the basis for changing the traditional approach. In the first case, they are mainly low and medium in value, in the second case they are mostly high, which cannot but affect the accuracy of the forecast assessment of the proper values of body weight and CC (using regression equations). In addition, the use of multiple correlation and regression does not contradict the method of determining the level of physical development by the ratio of total physical dimensions.

The research involved 7-17 years old boys (n=1111) and girls (n=1133) from secondary schools in Kyiv (Ukraine).

The research methods included the analysis and generalization of data from special literature (21 sources on the topic of the article from the scientometric databases PubMed, Scopus, Web of Science Core Collection and others were used), anthropometry, correlation and regression analyses.

RESULTS

Since the tables are developed according to age and gender features, it is first necessary to establish the age of a high schooler on the day of the study in order to assess his physical development. It is determined by subtracting the date of the high schooler birth from the date of the study.

Indicators of height are limited by sigma deviations within X±0.67σ (average values), from X+0.68σ to X+1.5σ (above average), from X+1.6σ and above (high), from X–0.68σ to X–1.5σ (below average), from X–1.6σ and below (low). Knowing the gender and age of the high schooler, it is determined according to the proper table to which group he belongs (by height): average, above average, below average, high, low.

The horizontal column includes the indicators of CC (or weight) of the subject of interest and the intersection of the actual data of his height and CC (or weight) determines the proper value of weight (or CC). Then the obtained weight (CC) is compared with the actual one and the less value is subtracted from the larger value of weight (CC) with assigning a sign of the greater value (therefore, if the high schooler has a weight (CC) greater than he should have according to the data of his height and CC (weight), the sign "+" is assigned, if less, then the sign "-" is assigned. The resulting difference is divided by the partial sigma: for weight - σ_{R-1}, for CC - σ_{R-2} (Tables 1, 2) and it is determined on how many partial sigma the weight (CC) of the high schooler of interest is greater or less (depending on the sign of the difference found) compared to the one he should have for a given height and CC (weight). If the value obtained is within ± $0.67\sigma_R$, then the weight (CC) is average, from $0.68\sigma_R$ to $1.5\sigma_R$ – above average, from $-0.68\sigma_R$ to $-1.5\sigma_R$ – below average, from $1.6\sigma_R$ and above – high, from $-1.6\sigma_R$ and below – low.

Here is an example: a 10 years old boy has a height of 143 cm, weight – 35.6 kg, CC during the pause – 69.2 cm. The table shows that the height of a 10 years old boy of 143 cm is within X±0.67σ, i. e. it is average. The proper weight for a height of 143 cm and CC of 69.2 cm should make 35.3 kg, and the proper value of CC at this height and weight of 35.6 kg – 69.0 cm. The partial sigma (σ_R) for the weight is 2.12, and for CC – 1.95. 35.6-35.3=0.3 (kg); 69.2-69.0=0.2 (cm). Both obtained numbers are within one partial sigma (±2.12×0.67=±3.54 for weight and ±1.95×0.67=±1.31 for CC), therefore, the weight and CC of the boy, as well as his height, are average, i.e. his physical development is harmonious (good).

However, there are other options in which, for example, the high schooler's height will be higher or lower than average one, and the weight or CC may be of a different value. Taking this into account and based on the recommendations [6], the high schoolers can be divided into 4 groups according to the level of their physical development:

1. High schoolers with good physical development, i. e. with average, above average, high and below average indicators of height at average and above average indicators of weight and CC.
2. High schoolers with excessive physical development, i. e. with the same indicators of height as in the first group, but with high indicators of weight and CC or only one of them.
3. High schoolers with lower than average physical development, i. e. with average, above average and high indicators of height at below average indicators of body weight and CC (or one of them).
4. High schoolers with low level of physical development, i. e.:
   a) with high, above average and average indicators of height at low indicators of weight and CC or one of them;
   b) with indicators of height below average at below average and low indicators of weight and CC (or one of them);
   c) with low indicators of height.

To perform group assessment of physical development of different children's groups you need to determine the proportion of children with one or another level of physical development (good, excessive, below average and low) in each group (team). Individual assessment of physical development allows distinguishing children with disharmonious physical development among all of the high schoolers.

The assessment tables for children of a certain gender and age show the length of the body (height) in vertical direction and the weight of the body or chest circumference (CC) in horizontal direction on the left, depending on what is needed for determination: the proper values of CC or body weight (Table 3).

Table 1. Table of statistical data on the indicators of physical development of male high schoolers

Feature	Age	X	σ	R_1	R_2	b_1	b_2	b_3	b_4	a_1	a_2	σ_{R-1}	σ_{R-2}
Body length (cm)	7	130.4	6.57	-	-	0.1864	0.0671	-	-	-	-	-	-
	8	131.6	5.23	-	-	0.2716	0.0365	-	-	-	-	-	-
	9	137.7	4.39	-	-	0.3442	-0.1329	-	-	-	-	-	-
	10	141.9	7.11	-	-	0.4352	-0.1480	-	-	-	-	-	-
	11	146.4	5.72	-	-	0.2593	0.0051	-	-	-	-	-	-
	12	151.2	7.04	-	-	0.2190	0.0060	-	-	-	-	-	-
	13	157.7	8.07	-	-	0.3385	0.0500	-	-	-	-	-	-
	14	166.0	8.75	-	-	0.2901	0.0359	-	-	-	-	-	-
	15	171.6	7.44	-	-	0.4487	-0.1148	-	-	-	-	-	-
	16	177.3	7.77	-	-	0.5278	-0.1926	-	-	-	-	-	-
	17	179.0	5.68	-	-	0.1727	0.0828	-	-	-	-	-	-

Feature	Age	X	σ	R_1	R_2	b_1	b_2	b_3	b_4	a_1	a_2	σ_{R-1}	σ_{R-2}
Body weight (kg)	7	28.0	2.93	0.852	-	-	-	-	0.5403	-57.33	-	1.53	-
	8	28.0	3.12	0.820	-	-	-	-	0.6248	-58.60	-	1.79	-
	9	31.6	4.57	0.916	-	-	-	-	0.7084	-88.69	-	1.83	-
	10	33.7	4.42	0.877	-	-	-	-	0.6351	-86.42	-	2.12	-
	11	38.4	4.63	0.871	-	-	-	-	0.6273	-71.30	-	2.27	-
	12	39.1	4.24	0.888	-	-	-	-	0.6708	-61.91	-	1.94	-
	13	45.8	6.53	0.891	-	-	-	-	0.5229	-90.07	-	2.99	-
	14	53.8	6.43	0.882	-	-	-	-	0.5196	-83.83	-	3.01	-
	15	57.7	5.09	0.887	-	-	-	-	0.6429	-91.93	-	2.33	-
	16	64.7	6.36	0.801	-	-	-	-	0.6137	112.14	-	3.12	-
	17	65.6	5.06	0.716	-	-	-	-	0.3631	-74.43	-	3.54	-

Feature	Age	X	σ	R_1	R_2	b_1	b_2	b_3	b_4	a_1	a_2	σ_{R-1}	σ_{R-2}
Chest circumference (cm)	7	64.7	2.07	-	0.835	-	0.9330	-	-	-	41.17	-	1.13
	8	65.1	2.73	-	0.784	-	0.7811	-	-	-	42.80	-	1.70
	9	67.2	3.58	-	0.900	-	1.0849	-	-	-	63.10	-	1.56
	10	67.6	3.20	-	0.795	-	0.8626	-	-	-	67.34	-	1.95
	11	70.8	3.76	-	0.852	-	1.0122	-	-	-	45.99	-	1.95
	12	71.5	3.74	-	0.868	-	0.9495	-	-	-	44.36	-	1.87
	13	74.6	5.17	-	0.871	-	1.1004	-	-	-	42.69	-	2.53
	14	78.7	5.04	-	0.862	-	1.1364	-	-	-	44.81	-	2.60
	15	81.3	4.49	-	0.827	-	0.8936	-	-	-	63.87	-	2.54
	16	85.6	5.36	-	0.807	-	0.9717	-	-	-	80.11	-	3.17
	17	86.7	3.36	-	0.714	-	1.2574	-	-	-	48.11	-	2.35

Table 2. Table of statistical data on the indicators of physical development of female high schoolers

Feature	Age	X	σ	R_1	R_2	b_1	b_2	b_3	b_4	a_1	a_2	σ_{R-1}	σ_{R-2}
Body length (cm)	7	126.9	4.21	-	-	0.4082	-	-0.2596	-	-	-	-	-
	8	129.6	5.20	-	-	0.4502	-	-0.0999	-	-	-	-	-
	9	134.2	5.45	-	-	0.2480	-	0.0015	-	-	-	-	-
	10	143.2	7.60	-	-	0.4006	-	-0.1314	-	-	-	-	-
	11	147.3	7.76	-	-	0.4353	-	-0.1507	-	-	-	-	-
	12	153.9	6.00	-	-	0.6094	-	-0.0920	-	-	-	-	-
	13	160.2	6.62	-	-	0.4660	-	-0.1710	-	-	-	-	-
	14	162.4	6.12	-	-	0.3923	-	-0.0309	-	-	-	-	-
	15	165.3	5.11	-	-	0.5525	-	-0.0282	-	-	-	-	-
	16	165.6	5.31	-	-	0.3451	-	-0.1434	-	-	-	-	-
	17	166.6	5.81	-	-	0.3783	-	0.0170	-	-	-	-	-
Feature	**Age**	**X**	**σ**	**R_1**	**R_2**	**b_1**	**b_2**	**b_3**	**b_4**	**a_1**	**a_2**	**σ_{R-1}**	**σ_{R-2}**
Body weight (kg)	7	22.9	2.29	0.796	-	-	-	-	0.7899	-61.94	-	1.40	-
	8	25.4	3.30	0.798	-	-	-	-	0.7801	-60.24	-	1.98	-
	9	28.8	3.64	0.857	-	-	-	-	0.7223	-55.14	-	1.89	-
	10	34.2	4.87	0.868	-	-	-	-	0.6318	-83.74	-	2.43	-
	11	37.1	6.19	0.912	-	-	-	-	0.7199	-88.53	-	2.55	-
	12	42.9	7.39	0.857	-	-	-	-	0.6372	-110.09	-	3.83	-
	13	47.6	6.33	0.895	-	-	-	-	0.5346	-121.50	-	2.83	-
	14	52.4	6.49	0.811	-	-	-	-	0.4759	-89.77	-	3.78	-
	15	55.7	5.76	0.732	-	-	-	-	0.4399	-99.47	-	3.91	-
	16	56.6	3.32	0.684	-	-	-	-	0.4590	-67.35	-	2.42	-
	17	59.3	5.83	0.767	-	-	-	-	0.3368	-105.96	-	3.73	-
Feature	**Age**	**X**	**σ**	**R_1**	**R_2**	**b_1**	**b_2**	**b_3**	**b_4**	**a_1**	**a_2**	**σ_{R-1}**	**σ_{R-2}**
Chest circumference (cm)	7	61.0	2.22	-	0.663	-	0.5417	-	-	-	75.85	-	1.66
	8	62.2	3.65	-	0.664	-	0.4393	-	-	-	55.31	-	2.73
	9	64.1	3.00	-	0.827	-	0.7910	-	-	-	43.07	-	1.69
	10	66.0	3.97	-	0.805	-	0.9179	-	-	-	63.21	-	2.34
	11	68.1	5.23	-	0.886	-	0.9023	-	-	-	63.63	-	2.61
	12	71.2	6.28	-	0.801	-	0.8313	-	-	-	58.02	-	3.76
	13	71.9	3.67	-	0.858	-	1.3134	-	-	-	73.85	-	1.87
	14	73.9	4.43	-	0.779	-	1.0625	-	-	-	43.93	-	2.76
	15	73.5	4.19	-	0.665	-	0.8682	-	-	-	53.63	-	3.13
	16	74.8	2.80	-	0.642	-	0.8956	-	-	-	72.51	-	2.15
	17	75.0	2.63	-	0.732	-	1.3637	-	-	-	52.18	-	1.78

Conventional signs:

R_1 – coefficient of multiple correlation between the indicators of body weight and body length and CC;

R_2 – the same, but between the indicators of CC and body length and body weight;

b_1 - b_4 – regression coefficients between the indicators of body length and body weight, body weight and CC, body length and CC and CC and body weight, respectively;

a_1, a_2 – intercept terms of regression equations for body weight and CC, respectively;

σ_{R-1} – partial sigma of body weight indicators;

σ_{R-2} – partial sigma of CC indicators

Table 3. Fragment of assessment of proper body weight and chest circumference in 10 years old boys (average height)

Body length (cm)	Chest circumference (cm)														
	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
138	22.8	23.7	24.5	25.4	26.3	27.1	28.0	28.8	29.7	30.6	31.4	32.3	33.2	34.0	34.9
139	23.2	24.1	25.0	25.8	26.7	27.6	28.4	29.3	30.1	31.0	31.9	32.7	33.6	34.5	35.3
140	23.7	24.5	25.4	26.3	27.1	28.0	28.9	29.7	30.6	31.4	32.3	33.2	34.0	34.9	35.8
141	24.1	25.0	25.8	26.7	27.6	28.4	29.3	30.2	31.0	31.9	32.7	33.6	34.5	35.3	36.2
142	24.5	25.4	26.3	27.1	28.0	28.9	29.7	30.6	31.4	32.3	33.2	34.0	34.9	35.8	36.6
143	25.0	25.8	26.7	27.6	28.4	29.3	30.3	31.0	31.9	32.7	33.6	34.5	35.3	36.2	37.1
144	25.4	26.3	27.1	28.0	28.9	29.7	30.6	31.5	32.3	33.2	34.0	34.9	35.8	36.6	37.5
145	25.9	26.7	27.6	28.4	29.3	30.3	31.0	31.9	32.8	33.6	34.5	35.3	36.2	37.1	37.9
146	26.3	27.2	28.0	28.9	29.7	30.6	31.5	32.3	33.2	34.1	34.9	35.8	36.6	37.5	38.4

Body length (cm)	Chest circumference (cm)													
	72	73	74	75	76	77	78	79	80	81	82	83	84	85
138	35.7	36.6	37.5	38.3	39.2	40.1	40.9	41.8	42.6	43.5	44.4	45.2	46.1	47.0
139	36.2	37.0	37.9	38.8	39.6	40.5	41.4	42.2	43.1	43.9	44.8	45.7	46.5	47.4
140	36.6	37.5	38.3	39.2	40.1	40.9	41.8	42.7	43.5	44.4	45.2	46.1	47.0	47.8
141	37.1	37.9	38.8	39.6	40.5	41.4	42.2	43.1	44.0	44.8	45.7	46.5	47.4	48.3
142	37.5	38.3	39.2	40.1	40.9	41.8	42.7	43.5	44.4	45.3	46.1	47.0	47.8	48.7
143	37.9	38.8	39.6	40.5	41.4	42.2	43.1	44.0	44.8	45.7	46.5	47.4	48.3	49.1
144	38.4	39.2	40.1	40.9	41.8	42.7	43.5	44.4	45.3	46.1	47.0	47.8	48.7	49.6
145	38.8	39.7	40.5	41.4	42.2	43.1	44.0	44.8	45.7	46.6	47.4	48.3	49.1	50.0
146	39.2	40.1	41.0	41.8	42.7	43.5	44.4	45.3	46.1	47.0	47.9	48.7	49.6	50.4

Body length (cm)	Body weight (kg)													
	22	23	24	25	26	27	28	29	30	31	32	33	34	35
138	60.9	61.5	62.2	62.8	63.4	64.1	64.7	65.3	66.0	66.6	67.2	67.9	68.5	69.1
139	60.7	61.4	62.0	62.6	63.3	63.9	64.6	65.2	65.8	66.5	67.1	67.7	68.4	69.0
140	60.6	61.2	61.9	62.5	63.1	63.8	64.4	65.0	65.7	66.3	66.9	67.6	68.2	68.9
141	60.4	61.1	61.7	62.4	63.0	63.6	64.3	64.9	65.5	66.2	66.8	67.4	68.1	68.7
142	60.3	60.9	61.6	62.2	62.8	63.5	64.1	64.7	65.4	66.0	66.6	67.3	67.9	68.6
143	60.2	60.8	61.4	62.4	62.7	63.3	64.0	64.6	65.2	65.9	66.5	67.1	67.8	68.4
144	60.0	60.6	61.3	61.9	62.5	63.2	63.8	64.4	65.1	65.7	66.4	67.0	67.6	68.3
145	59.9	60.5	61.1	61.8	62.4	63.0	63.7	64.3	64.9	65.6	66.2	66.8	67.5	68.1
146	59.7	60.3	61.0	61.6	62.2	62.9	63.5	64.2	64.8	65.4	66.1	66.7	67.3	68.0

Body length (cm)	Body weight (kg)														
	36	37	38	39	40	41	42	43	44	45	46	47	51	52	53
138	69.8	70.4	71.1	71.7	72.3	73.0	73.6	74.2	74.9	75.5	76.1	76.8	79.3	79.9	80.6
139	69.6	70.3	70.9	71.5	72.2	72.8	73.4	74.1	74.7	75.3	76.0	76.6	79.2	80.0	80.4
140	69.5	70.1	70.8	71.4	72.0	72.7	73.3	73.9	74.6	75.2	75.8	76.5	79.0	79.6	80.3
141	69.3	70.0	70.6	71.2	71.9	72.5	73.1	73.8	74.4	75.1	75.7	76.3	78.9	79.5	80.1
142	69.2	69.8	70.5	71.1	71.7	72.4	73.0	73.6	74.3	74.9	75.5	76.2	78.7	79.4	80.0
143	69.0	69.7	70.3	70.9	71.6	72.2	72.9	73.5	74.1	74.8	75.4	76.0	78.6	79.2	79.8
144	68.9	69.5	70.2	70.8	71.4	72.1	72.7	73.3	74.0	74.6	75.2	75.9	78.4	79.1	79.7
145	68.7	69.4	70.0	70.7	71.3	71.9	72.6	73.2	73.8	74.5	75.1	75.7	78.3	78.9	79.5
146	68.6	69.2	69.9	70.5	71.1	71.8	72.4	73.0	73.7	74.3	74.9	75.6	78.1	78.8	79.4

DISCUSSION

The analysis of the studied sources [7, 8] shows that individual organs and systems of a high schooler's body are developed and reach a mature type of functioning during all school years. All these processes happen according to clearly defined biological laws of organism's development. Only being aware of these laws, the parents and teachers will be able to help high schoolers improve physically. According to the experts [9, 10], the assessment of the level of development according to morphofunctional indicators is an important criterion of school maturity (correspondence between calendar and biological age), a prerequisite for scientifically sound dosing of mental and physical activities.

The study of the physical development issues is associated with many scientific problems: it is a study of peculiarities of physical development of high schoolers in different regions of the country; search for the reasons causing acceleration of rates of physical development of children and teenagers; differentiated approach in the process of physical education taking into account the peculiarities of physical development of high schoolers of one form and gender [11-13].

Rational organization of physical training of high schoolers is impossible today without objective testing of the level of their physical development [14]. Timely testing is a guarantee in preventing possible disorders in the high schoolers' health [15]. Scientists pay a lot of attention to methods of studying physical development. Somatometry is considered to be the main method among them, which includes determining the indicators of body weight and chest circumference [16, 17].

The difference between the author's method of assessing the level of physical development of high schoolers is the development of tables of proper values of body weight not only taking into account body length (as was the case with predecessors), but also considering the actual values of chest circumference. Accordingly, the assessment tables of proper chest circumference indicators were developed taking into account the combined effect of body length and body weight. Multiple correlation and regression were used for this purpose. The results of our research expand the conclusions of the works of many scientists [18-21] and complement them.

CONCLUSIONS

1. Rational organization of high schoolers' physical education is impossible without objective assessment of their physical development. Proper testing in a timely manner is the key to preventing physical strain and health problems.
2. The use of multiple correlation and regression in the development of standards for physical development of 7-17 years old high schoolers, in contrast to the traditional approach, on the basis of pair correlation, significantly increases the accuracy of assessing the proper values of body weight and chest circumference, and with the rest the high schooler physical development.
3. Statistical data of summary tables are the basis for drawing up standards of physical development of high schoolers. The availability of standards of physical development of high schoolers is essential for assessing the socio-economic and hygienic living conditions of citizens. The level of physical development, together with such indicators as fertility and morbidity, are key indicators of social health.

Prospects for further research are to develop tables to assess the physical development of university students based on the interaction of total physical dimensions.

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