Original Article

Prognostic assessment of physical fitness of schoolchildren with health disorders using functional indicators

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Abstract:

According to the current Decree № 518/674 of the Ministry of Healthcare of Ukraine and the Ministry of Education and Science of Ukraine, the schoolchildren with health disorders belong to the preparatory and special groups for Physical Culture classes and are not allowed to perform educational standards for Physical Culture that makes impossible to assess the state of their physical fitness. This, in its turn, does not promote the schoolchildren's interest in improving motor skills. Thus, the goal of the research was to find a way to assess the physical fitness of the schoolchildren of middle school school age in the preparatory and special medical groups being equivalent to the assessment of their physical fitness level according to control standards in Physical Culture. The indicators were compared using Student's t-test. The values were considered to be statistically reliable at $p < 0.05$. For nominal variables, the correlation was determined by correlation tables using the known Pearson's chi-squared test (χ^2). To determine the dependence of indicators on acting factors, we used regression analysis. The results showed the correlation between the state of children's health on the one hand and functional parameters of the body and physical fitness on the other hand ($\chi^2=11.68 - 50.22$; $p<0.001$). On the basis of the obtained data, mathematical model was created which would allow to assess the physical training of schoolchildren with health disorders belonging to the preparatory and special medical groups for Physical Culture classes based only on the functional state of a child, thus, promoting an increasing interest to Physical training.

Keywords: schoolchildren, Physical Culture, regression analysis.

Introduction

According to the current Decree № 518/674 of the Ministry of Healthcare of Ukraine and the Ministry of Education and Science of Ukraine, the schoolchildren with health disorders belong to the preparatory and special groups for Physical Culture classes and are not allowed to perform educational standards for Physical Culture that makes impossible to assess the state of their physical fitness. This, in its turn, does not promote the schoolchildren's interest in improving motor skills. In modern life, systematic physical training is known not only to compensate the lack of movements necessary for normal functioning of the body but to be the most effective means of improving human health.

The goal of the research was to find a way to assess the physical fitness of the schoolchildren of middle school school age in the preparatory and special medical groups being equivalent to the assessment of their physical fitness level according to control standards in Physical Culture.

To achieve the goal set we had to solve the following tasks:

- 1) to investigate the features of functional state and physical fitness of the middle school age pupils with and without chronic somatic diseases;
- 2) to determine the degree of influence of the schoolchildren's body functionality on the formation of their physical fitness;
- 3) to find an adequate way to assess the level of physical fitness of schoolchildren with health disorders, based on the functional state of the body.

Material & methods

The research was conducted on the basis of secondary school № 6 with traditional type of education, Cherkasy, Ukraine. The study involved 382 middle school age pupils, including 274 pupils who had a history of chronic physical disease and belonged to the preparatory and special medical groups for Physical Education classes and 108 pupils without health disorders.

The physical fitness state of schoolchildren was determined by "The Curriculum on Physical Training for Secondary Schools (5 – 9 classes)" (auth. T.Yu. Krutsevych and others, 2009), according to the results of control exercises: "shuttle" running 4×9 m (s); bent arm hang on the crossbar or pull up while hanging in a prone position; body lift from a prone position to a sitting position for 30 seconds (the number of times); tilt forward from a sitting position (cm); running on 30(60) m (s); standing long jump (cm).

The indicators of the control standards were assessed, and according to them the schoolchildren got 0, 1 or 2 points for each type of control exercises. Thus, a pupil could get maximum 12 points for doing 6 control exercises. Complex assessment of exercises of the test was made according to the sum of scored points, by which the pupil's performance was determined: elementary (0 – 3 points), medium (4 – 6 points), sufficient (7 – 9 points), high (10 – 12 points).

Functional state of the body of the middle school age pupils was determined by the integral indicators:

- double product index or Robinson (DPI), which reflects formation features of “economization functions” and systolic heart function (formula 1):

$$DPI = \frac{HR \times SBP}{100} \quad (1)$$

where: DPI – double product (conventional units – in Fr.); HR – heart rate (beats / min); SBP – systolic blood pressure (mm Hg);

- adaptive potential (AP according to the formula of R.M. Baevsky, A.P. Berseneva), which reflects adaptive reactions of the whole organism (formula 2):

$$AP = 0.011 \times HR + 0.014 \times SBP + 0.008 \times DBP + 0.014 \times A + 0.009 \times BW - (0.009 \times BL + 0.27) \quad (2)$$

where: AP – adaptive potential (in Fr.); HR – heart rate (beats / min); SBP – systolic blood pressure (mm Hg); DBP – diastolic blood pressure (mm Hg); A – age (years), BW – body weight (kg); BL – body length (cm);

- physical condition index (PCI by Pirogova's formula), which describes the physical condition of a child (formula 3):

$$PCI = \frac{700 - 3 \times HR - 2.5 \times MAP - 2.7 \times A + 0.28 \times BW}{350 - 2.6 \times A + 0.21 \times BL} \quad (3)$$

where: PCI – physical condition index (in Fr.); HR – heart rate (beats / min); BW – body weight (kg); A – age (years); BL – body length (cm); MAP – mean arterial pressure determined by Hikem's formula (formula 4):

$$MAP = \frac{1}{3}(SBP - DBP) + DBP \quad (4)$$

where: MAP – mean arterial pressure (mm Hg); SBP – systolic blood pressure (mm Hg); DBP – diastolic blood pressure (mm Hg);

- the quality index of the cardiovascular system reaction (IQR) to the dosed physical loading in 20 sit-ups in 30 seconds (by B.P. Kushelevsky's formula), which is an objective criterion of the functional state of circulatory system (formula 5):

$$IQR = \frac{PP_2 - PP_1}{HR_2 - HR_1} \quad (5)$$

where: IQR – quality index of the circulatory system reactions (in Fr.); PP_2 – pulse pressure after loading (mm Hg); PP_1 – pulse pressure before loading (mm Hg); HR_2 – heart rate after loading (beats / min); HR_1 – heart rate before loading (beats / min);

- the percentage of the increase in heart rate (HR) and pulse pressure (PP) after loading, which reflects the adequacy of cardio-vascular system to the dosed loading (formula 6, formula 7):

$$HRpl. = \frac{(HR_2 - HR_1)}{HR_1} \times 100\% \quad (6)$$

$$PPpl. = \frac{(PP_2 - PP_1)}{PP_1} \times 100\% \quad (7)$$

where: HRpl. – the increase of heart rate after the dosed physical loading (%); PPpl. – the increase of pulse pressure after the dosed physical loading (%); HR_1 – heart rate before loading (beats / min); HR_2 – heart rate after loading (beats / min); PP_1 – pulse pressure before loading (mm Hg); PP_2 – pulse pressure after the load (mm Hg);

- respiratory index (RI that was determined by dividing the vital lung capacity into body weight), which is determined by the functionality of the respiratory system (formula 8):

$$RI = \frac{VLC}{BW} \quad (8)$$

where: RI – respiratory index (mL / kg); VLC – vital lung capacity (mL); BW – body weight (kg).

Statistics

In the statistical analysis of data, the average percentage (P) was evaluated by formula 9:

$$P = \frac{n}{N} \times 100 \quad (\%), \quad (9)$$

where: n – the number of objects that have necessary characteristics; N – the total number of sample.

The error of average percentage (m) was calculated by formula 10:

$$m = \sqrt{\frac{p \times (100 - p)}{N}} \quad (\%) \quad (10)$$

where: p – average percentage; N – the total number of sample.

The indicators were compared using Student's t-test. The data were considered statistically valid at $p < 0.05$.

For nominal variables, the correlation was determined by correlation tables using Pearson's chi-squared test (χ^2).

To determine the dependence of indicators from acting factors we used regression analysis.

The models of multiple linear regression were as follows (formula 11):

$$y = a_0 + a_1x_1 + a_2x_2 + \dots + a_mx_m \quad (11)$$

where: $a_0, a_1, \dots, a_m$ – parametres (coefficients) of the model for all m-factors that are analyzed.

To compare the significance of factor impact on the studied function, the equation was reaccounted in standard variables and imagined recwas recorded in the so-called "beta coefficients" (formula 12):

$$y = \beta_1x_1 + \beta_2x_2 + \dots + \beta_mx_m \quad (12)$$

The coefficients of this equation allowed to compare different factors according to their impact on the final (ultimate) function. Thus, the higher the value of "beta coefficient", the more dependent the function on the corresponding factor and vice versa.

Besides, beta coefficients allowed to evaluate the relative "contribution" of factors (d_i) to function variability. In particular, the variability associated with the i-th factor, may be considered equal to the proportion of square of the corresponding beta coefficient from the total of all squares of "beta coefficients" (formula 13):

$$d_i = \frac{\beta_i^2}{\sum_{i=1}^m \beta_i^2} \times 100\% \quad (13)$$

In general, the following research methods were used in the study: theoretical analysis and synthesis; biomedical, pedagogical and mathematical methods.

The package of Excel MS Office was used for intermediate calculations. The main part of mathematical processing was performed on a personal computer using the standard statistical package of STATISTICA 5.0.

Results

To assess the children's performance in Physical Culture considering the results of showing the main physical qualities comprhensively, we determined the composition of properties that form the level of physical fitness of the middle school age pupils with a different health state. The assessment of the development of schoolchildren's main physical qualities according the indicators of control standards in Physical Education showed that the schoolchildren with chronic diseases had significantly lower indicators in most exercises compared with healthy children ($p < 0.05$ – $p < 0.001$) (fig.1).

Fig.1. The indicators of control standards in Physical Education for pupils with and without chronic diseases (in points): reliable differences between indicators at the level of $p < 0.05$; ** $p < 0.01$; *** – $p < 0.001$.

The differences between the level of Physical Culture performance of schoolchildren with and without chronic diseases were found on the basis of comprehensive assessment of the motor test results. 65.10 ± 3.44 % of schoolchildren with chronic diseases achieved only primary and medium levels (19.79 ± 2.88 % and 45.31 ± 3.59 % respectively), and 34.90 ± 4.44 % of schoolchildren had high and sufficient level (29.69 ± 3.30 % and 5.21 ± 1.60 % respectively) (fig. 2).

Fig.2. The level of Physical Culture performance of the pupils of middle school age with and without chronic diseases (%) ** – reliable differences between the corresponding indicators at $p < 0.01$; *** – $p < 0.001$.

Unlike children with health disorders, 27.95 ± 3.54 % of practically healthy children had primary and medium levels of Physical Culture performance (8.70 ± 2.22 % and 19.25 ± 3.11 % respectively), and 72.05 ± 3.54 % of schoolchildren had sufficient and high levels of performance (58.39 ± 3.88 % and 13.66 ± 2.71 % respectively). These results show that the key reason of control test performance in Physical Culture is higher health level of the schoolchildren since 73.91 ± 3.46 % of healthy schoolchildren and only 39.02 ± 4.40 % of children with chronic diseases had sufficient and high levels of performance ($p < 0.001$).

Physical fitness is known to depend on physical fitness features, human functional opportunities, etc. (Biletska, 2006; Mytskan & Potashnyuk, 2011; Vaynbaum et al., 2002; Mosiychuk, 2004; Suvorova, 2002). Therefore, we studied not only the development level of physical qualities but the features of body functioning of middle school age children with and without chronic diseases.

The obtained data show that early formation of chronic pathology in the middle school age is accompanied by the decrease in functional opportunities of schoolchildren's body that was demonstrated in the high level of unfavorable characteristics (compared with healthy children): double product index or Robinson (DPI in 63.50 ± 2.91 % cases), physical condition index (PCI in 47.45 ± 3.02 % of cases), adaptive potential (AP in 52.55 ± 3.02 % of cases), quality indicator of the circulatory system reactions (IQR in 20.44 ± 2.44 % of cases), frequency reactions of the heart rate being inadequate to standard physical loading (HR at 67.15 ± 2.84 % of cases) and minute volume of blood circulation (MVBC in 64.96 ± 2.88 % of cases), step and dystonic reactions of cardiovascular system (16.79 ± 2.58 % of cases) (fig. 3).

Fig. 3. Unfavourable features of functional state of the middle school age children (%) * – reliable differences between these indicators of schoolchildren with and without chronic diseases at the level of $p < 0.05$; ** – $p < 0.01$; *** – $p < 0.001$.

The conducted research showed the correlation between the state of children's health on the one hand and integral characteristics of the functional state and the development of physical qualities on the other hand, such as:

- Index of physical condition (PCI $\chi^2 = 12.21$; $p < 0.001$);
- Adaptative potential (AP $\chi^2 = 19.69$; $p < 0.001$);
- Efficiency of the cardiovascular system (DPI $\chi^2 = 15.27$; $p < 0.001$);
- Reactivity of the cardiovascular system (HR and MVBC changes to the standard exercises, respectively, $\chi^2 = 44.39$; $p < 0.001$ and $\chi^2 = 30.26$; $p < 0.001$);
- Physical fitness ($\chi^2 = 50.22$; $p < 0.001$), including power-speed ($\chi^2 = 19.39$; $p < 0.001$), agility ($\chi^2 = 16.92$; $p < 0.001$), the power of the arm flexors ($\chi^2 = 16.57$; $p < 0.001$), and trunk muscles ($\chi^2 = 11.68$; $p < 0.001$), speed ($\chi^2 = 15.17$; $p < 0.001$).

Since the existence of correlation between health state, physical fitness and functional characteristics of the body has been confirmed, it helps to create a functional model that will determine the probable level of physical fitness of middle school age children with and without chronic diseases, which are not allowed to perform control standards in Physical Culture due to their health state. The mathematical model synthesized in result is as follows (fig. 4):

Regression Summary for Dependent Variable: TPT (2.sta)						
R= .98112945 RI= .96261501 Adjusted RI= .96118810						
F(5,131)=674,62 p<0,0000 Std.Error of estimate: 7,5138						
	BETA	St. Err. of BETA	B	St. Err. of B	t(131)	p-level
DPI	0,952616	0,37508	0,3590476	0,14137	2,539766	0,012261
AP	-0,50682	0,388588	-9,5300642	7,306901	-1,30426	0,194433
PCI	0,40709	0,108929	27,580001	7,379831	3,737213	0,000277
RI	0,258546	0,148766	0,2425589	0,139567	1,737937	0,084572
CDN	-0,12904	0,042459	-2,1012869	0,691417	-3,0391	0,002865
	1,413561					
						100

Fig. 4. The content of regression function to determine the level of physical fitness of middle school age children with chronic somatic diseases.

The final formula is:

$$y = 0.95x_1 - 0.51x_2 + 0.41x_3 + 0.26x_4 - 0.13x_5 \quad (F=674; p < 0.001),$$

where: y – (TPT) – the success of training on PT lessons of the middle school age children with chronic somatic diseases (points); x_1 – DPI (in. Fr.); x_2 – AP (in. Fr.); x_3 – PCI (in. Fr.); x_4 – RI (mL / kg); x_5 – CDN – the number of chronic diseases and pathological conditions.

The use of multivariate regressive analysis allowed to determine the degree of influence of various factors (obtained by determining "beta coefficient") on the formation of physical fitness of schoolchildren with chronic diseases: the following indicators made the greatest contribution to the mathematical model structure: double product index (DPI), which is 64.20 %, regressive adaptation potential model (AP) – 18.17 %, the index of physical condition (PCI) – 11.72 %, respiratory index (RI) – 4.73 %, the number of chronic diseases and pathological conditions (CDN) – 1.18 %.

Thus, the created regressive model allows to assess approximately the level of physical fitness of the schoolchildren belonging to preparatory and special medical groups, which is impossible to determine for today.

Discussion

Scientists discuss the correlation between the state of health and functioning of the main physiological systems of the body and physical performance. Some authors stress that chronic pathology is not decisive for the formation of physical performance and point out the lack of difference with the indicators of healthy children (Chernaia et al., 2007). However, several studies indicate the opposite, that there is a close correlation between the state of health, physical fitness, morphological and functional characteristics of the body (Biletska, 2006; Mytskan & Potashnyuk, 2011; Vaynbaum et al., 2002; Mosiychuk, 2004; Suvorova, 2002).

Our study of the health state of the middle school age children showed that the early formation of chronic diseases, in the middle school age, is accompanied by a decrease in their body functionality and physical fitness. The specialists in the field of physical culture and medicine stress the existence of correlation between the children's health state and physical fitness. In particular, Biletska (2006) emphasizes the connection of physical fitness and functional state of schoolchildren. Mytskan & Potashnyuk (2011) consider physical fitness to be an indicator of physiological reserves of the organism. Vaynbaum (2002) stresses the correlation between the development of physical qualities (especially endurance) and health state. Mosiychuk (2004) notes that the focused continuous impact on all motor functions of children's organism contributes to the correction of deviations in the cardiovascular system, the expansion of reserve adaptive capacity of the body. Suvorova (2004)

emphasizes the correlation between the results of motor tests and functional performance of the body, opening the way to the focused increase of the functional capacity of children body by means of physical training.

The correlation between health state, physical fitness and functional capacity of the body of the middle school age children that was confirmed by our study and a number of national researches, shows the possibility of directional positive impact on the health state and physical fitness of the schoolchildren with chronic somatic diseases by increasing functional and adaptive capacities of their body. This thesis is confirmed by a number of foreign scientists. Thus, Carlos Marta, Daniel A. Marinho and Mário C. Marques (2012) point out that physical training of children improves with strengthening cardio-respiration system. The researches of Maryana Chekhovska, Liubov Chekhovska (2016) confirm the positive effect of physical therapy on not only functional state and physical development of the children with chronic heart failure but on the stabilization of their mood, better psychosocial adaptation and even reinforcement of the drug therapy action. The researches of Anastasia Topalidou, Georgia-Maria Dafopoulou (2013) show that sufficient physical activity during childhood can reduce overweight and obesity and is essential for the prevention of obesity, which is the starting point for many diseases of cardiovascular, respiratory, endocrine system and even mortality in adulthood.

Thus, the application of physical training in childhood and adolescence helps not only to solve the problems of maintaining schoolchildren's health, but also a healthy way of life in older age, contributing to the full implementation of social functions by a man.

Considering extremely positive impact of Physical Culture in the rehabilitation of the persons with somatic diseases; in the complex rehabilitation of children, one should take into account the state of their health and the level of their physical fitness. At the same time, positive practice shows that the use of such individual data about the physical state of a man can be applied in the development of training programs to increase the efficiency of physical training and sport. Thus, O. Ivashchenko, O. Khudolii, T. Yermakova, S. Iermakov, N. Nosko, Y. Nosko, M. Cieřlicka, R. Muszkieta, B. Stankiewicz, H. Żukowska (2015 – 2016), using factor and discriminant analysis to investigate the physical state of both schoolgirls and schoolboys, come to a conclusion about the feasibility of using structural and functional analysis in practice of physical training of children and adolescents. Milenko B. Milosevic, Milos M. Milosevic (2013) propose the complex model of metric characteristics, which allows to assess the current state of football players and to predict their sport results providing a huge advantage in the daily training of athletes.

Therefore, today the general practice in physical education is the application of mathematical forecasting techniques that increase the quality of medical and pedagogical control in Physical Culture and sport. Considering the positive experience of national and foreign scientists in the application of forecasting models, we synthesized regression function (represented above), which allows to assess the level of physical fitness of the schoolchildren with health disorders belonging to the preparatory and special medical groups for Physical Culture classes on the basis of the data of body functional state.

Conclusions

1. The obtained data show the decrease of functional opportunities of cardio-respiratory system, physical state, adaptive reserves and physical fitness in 50-60% of the schoolchildren with chronic somatic diseases.

2. The correlation between the health state, physical fitness and functional opportunities of children's body confirmed by our study shows the directed positive effect of recreational physical culture means on their physical state.

3. The regressive model created by us allows to assess the level of physical fitness of the schoolchildren with disorders in the health state on the basis of the functional parameters of their body.

We understand the convention of the assessment of schoolchildren's physical fitness; however, in our opinion, the use of such an individual approach will contribute to Physical Culture performance assessment of the schoolchildren with chronic somatic diseases. As a result, it helps to increase the interest of schoolchildren to physical training at Physical Culture classes and in the individual form.

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