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Надійшла до редакції 21.03.2017

ВИЗНАЧЕННЯ ФУНКЦІОНАЛЬНИХ МАРКЕРІВ ВІДНОСНОГО РИЗИКУ ФОРМУВАННЯ ХРОНІЧНИХ ЗАХВОРЮВАНЬ СУЧАСНИХ ШКОЛЯРІВ

Світлова О.Д.

FUNCTIONAL MARKERS' DEFINITIONS OF RELATIVE RISK IN THE DEVELOPING CHRONIC DISEASES FOR MODERN SCHOOLCHILDREN

SVIETLOVA O.D.
B. Khmelnytsky National University at Cherkasy, Ukraine

UDC 613.955 : 616-021[-036]

Keywords: schoolchildren, pathology, physical readiness, functional state, mathematical model, risk.

According to statistics of MHC in Ukraine and personal research, the aggravation of modern pupils were steadily progressing. Own observations showed that pathological affected pupils of all ages has increased significantly: between 1986 and 2015 it increased at primary school in 2,2 times ($p<0,001$), mainly in 2,0 times ($p<0,001$) in senior – 2,2 times ($p<0,001$) [1]. At the same time in the scientific literature emphasizes insufficient quality, but most important — the number of medical examinations during the period of schooling, poor diagnostics prepathological states, insufficient staffing states of health workers who carry out routine inspections of pupils [2-3].Today, the extremely important questions arise of monitoring the pupils' health, which will allow for intervention at the time of the early forms of disease formation, because only then can we hope for the suspension of these negative tendencies of modern children's health worsening.

The aim and objectives. The aim is to determine the conditions of developing chronic diseases of the secondary school age children for the selection of the "risk" persons of multiple pathology occurrence for further thorough examination by specialists in a medical setting.

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Світлова О.Д.
Черкаський Національний університет ім. Б. Хмельницького

***Актуальність**. Протягом останніх десятиліть в Україні відзначається процес погіршення стану здоров'я школярів. За період з 1986 по 2015 роки патологічна ураженість учнів істотно зросла: у молодшій школі – у 2,2 рази, у середній – удвічі, у старшій – у 2,2 рази. Тому нині надзвичайно актуальними є питання контролю над станом здоров'я школярів.*
***Метою дослідження** було виявити передумови формування хронічних захворювань у сучасних школярів.*
***Матеріали і методи.** У дослідженнях взяли участь 382 учні середнього шкільного віку, 274 з яких мали хронічні соматичні захворювання, 108 не мали порушень стану здоров'я. Оцінка відносного ризику виникнення патологічних змін у дітей з хронічними захворюваннями проводилася порівняно зі здоровими. Для визначення залежності показників від діючих факторів використовувався багатофакторний регресійний аналіз.*
***Результати**. У ході виконання роботи було виявлено функціональні маркери відносного ризику формування хронічних соматичних захворювань у дітей, а також недостатнього рівня фізичної підготовленості. Знайдено спосіб орієнтовної оцінки стану здоров'я дітей за функціональними показниками організму й рівнем фізичної підготовленості, що дозволяє виявити групу "ризику" виникнення патології.*

Ключові слова: учні, патологія, фізична підготовленість, функціональний стан, математична модель, ризик.

During the execution of research the following tasks are discussed:

1) investigate the functional state of the body and physical fitness of the secondary school age pupils with the presence and absence of chronic somatic diseases;

2) established the functional markers relative to the risk of developing chronic somatic diseases and low level of pupils'physical fitness;

3) find a way to approximate evaluation of the children's health of the secondary school age on indicators of functional status and physical fitness to identify of the "risk" persons of the pathological conditions formation.

Materials and methods. In the study involved 382 middle school age pupils, including 274 pupils who were diagnosed as a result of preventive medical examinations have chronic somatic diseases and were attributed to the third health group and 108 schoolchildren without significant violations in health.

To investigate the functional status and physical fitness of pupils, the following indicators are used: adaptive potential (AP), which is defined by Baevskyi, changes in heart rate (HR) and minute blood circulation volume (MVBC) after dosed physical load during the test of Martine as 20 sit-ups in 30 seconds, tentative comprehensive tests of the physical fitness assessment.

These indicators were defined as follows.

Adaptation potential (AP) was determined by the formula of Baevskyi, Bersenyeva (formula 1):

$$AP=0.011 \times HR+0.014 \times SBR+0.008 \times DBR+0.014 \times A+0.009 \times BW-(0.009xBL+0.27), \quad (1)$$

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

The percentage of heart rate increasing and minute blood circulation volume increasing (due to dosed physical load) was determined by comparing the data before loading and after (formula 2, formula 3):

$$HRpl. = \frac{(HR_2 - HR_1)}{HR_1} \times 100\% \quad (2)$$

$$MVBCpl. = \frac{(MVBC_2 - MVBC_1)}{MVBC_1} \times 100\% \quad (3)$$

where HRpl./MVBCpl. – the heart rate increasing/a minute blood circulation volume after exercises (%); $HR_1/MVBC_1$ – heart rate (beats/Min.)/minute volume of blood circulation (mL) before the exercises; $HR_2/MVBC_2$ – heart rate (beats/Min.)/MVBC (ml) after dosed physical load.

A minute volume of blood circulation after dosed physical load ($MVBC_2$) was determined by the following formula (formula 4):

$$MVBC_2 = SBV_2 \times HR_2, \quad (4)$$

where $MVBC_2$ — minute volume of blood circulation after the load (ml); SBV_2 – systolic blood volume after the load (ml); HR_2 – heart rate after the load (beats/Min.). Thus, SBV_2 calculated by the Starr formula (formula 5):

$$SBV_2 = 90.97+0.54 \times PP_2 - 0.57 \times DBP_2 \times A, \quad (5)$$

where SBV_2 – systolic blood volume after the load (ml); PP_2 – pulse pressure after the load (mm Hg. In.); DBP_2 – diastolic blood pressure after the load (mm Hg. In.); A – age in years.

The quality score reaction of the cardiovascular system (IQR) to dosed exercises as 20 sit-ups in 30 seconds (by B.P. Kushelevskyi's formula), which is an objective criterion of the functional state of the circulatory system (formula 6):

$$IQR = \frac{PP_2 - PP_1}{HR_2 - HR_1} \quad (6)$$

where IQR – quality indicator reactions of the circulatory system (in. Fr.); PP_2 – pulse pressure after the load (mm Hg. In.); PP_1 – pulse pressure before the load (mm Hg. In.); HR_2 – heart rate after the load (beats/Min.); HR_1 – heart rate before the load (beats/Min.).

Physical condition index (PhCI by Pirogova's formula), which describes the physical condition of the child (formula 7):

$$PhCI = \frac{700 - 3 \times HR - 2,5 \times ADP - 2,7 \times A + 0,28 \times BW}{350 - 2,6 \times A + 0,21 \times BL}$$

where PhCI – physical condition index (in. Fr.); HR – heart rate (beats/Min.); BW – body weight (kg); A – age (years); BL – body length (cm); ADP – the average dynamic pressure determined by the Hikema's formula (formula 8):

$$ADP = \frac{PP}{3} + DBP \quad (8)$$

where ADP – average dynamic pressure (mm Hg. In.); PP – pulse pressure (mm Hg. In.); DBP – diastolic pressure (mm Hg. In.).

Respiratory index (RI that was determined by dividing the vital lung capacity on body weight), which are determined by the functionality of the respiratory system (formula 9):

$$R^2 = \frac{VLC}{BW} \quad (9)$$

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

Double product index or Robinson (DPI), which reflects the patterns of formation of "economization functions" and systolic heart function (formula 10)

$$DPI = \frac{HR \times SBP}{100} \quad (10)$$

where DPI – double product index (in. Fr.); HR – heart rate (beats / Min.); SBP – systolic blood pressure (mm Hg. In.)

Physical training (PhT) was assessed by the average number of points earned by the student for each type of control exercises "shuttle" running 4 x 9 m; hang on the bar bent on hand or in pulling hang / hang in lying; ups torso from a prone position in a sitting position for 30 seconds; tilt forward from a sitting position; running at 30 m to 10 years old, 60 m for 11-14 years; long jump from the spot. In the case of a separate control exercise 1-4 points a pupil is assigned 0; 5-8 points is assigned 1; 9-12 points is assigned 2. Thus, for each type of control exercises pupil gets from 0 to 2 points, being able to score for the 6 control standards from 0 to 12 points.

Assessment of the relative risk was carried out as follows (formula 11):

$$RR = \frac{IR_i}{IR_0} \quad (11)$$

for which the confidence interval was defined as (formula 12):

$$e^{ln(RR) \pm 1,96 \sqrt{var\left[ln(RR)\right]}} \quad (12)$$

where ***e*** – the base of natural logarithm, approximately equal to 2,718; ln – logarithmic function, the natural logarithm.

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

Multiple linear regression models were as follows (formula 13):

$$y = a_0 + a_1x_1 + a_2x_2 + \ldots + a_mx_m \quad (13)$$

where a_0, a_i, …, a_m – model's (coefficients) options for all m-factors that are analyzed.

For comparison the importance of factors' impact on the studied equation's function reaccounted in standard variable and imagined recording the so-called "beta coefficients" (formula 14):

$$y = \beta_1x_1 + \beta_2x_2 + \ldots + \beta_mx_m. \quad (14)$$

The coefficients of this equation are allowed to conduct a comparison between the different factors according to their impact on final (the last) function. Thus, the greater value of "beta coefficient", the more dependent function of

ОПРЕДЕЛЕНИЕ ФУНКЦИОНАЛЬНЫХ МАРКЕРОВ ОТНОСИТЕЛЬНОГО РИСКА ФОРМИРОВАНИЯ ХРОНИЧЕСКИХ ЗАБОЛЕВАНИЙ СОВРЕМЕННЫХ ШКОЛЬНИКОВ

Светлова Е.Д.
Черкасский Национальный университет им. Б. Хмельницкого

***Актуальность**. В течение последних десятилетий в Украине отмечается процесс ухудшения состояния здоровья школьников. За период с 1986 по 2015 год патологическая пораженность учащихся всех возрастов существенно возросла: в младшей школе – в 2,2 раза, в средней – в 2,0 раза, в старшей – в 2,2 раза. Поэтому на сегодняшний день чрезвычайно актуальны вопросы контроля над состоянием здоровья школьников.*
***Цель**: выявить предпосылки формирования хронических заболеваний у современных школьников.*
***Материалы и методы.** В исследованиях приняли участие 382 учащихся среднего школьного возраста, среди которых 274 школьника имели хронические соматические заболевания, 108 школьников были без нарушений в состоянии здоровья. Оценка относительного риска возникновения патологических изменений у детей с хроническими заболеваниями проводилась в сравнении со здоровыми. Для определения зависимости показателей от действующих факторов использовался многофакторный регрессионный анализ.*
***Результаты**. В ходе выполнения работы были выявлены функциональные маркеры относительного риска формирования хронических соматических заболеваний у детей, а также недостаточного уровня физической подготовленности. Найден способ ориентировочной оценки состояния здоровья детей лишь по функциональным показателям организма и уровню физической подготовленности, что позволяет выявить группу "риска" возникновения патологии.*

Ключевые слова: учащиеся, патология, физическая подготовленность, функциональное состояние, математическая модель, риск.

the factor and vice versa.

Besides, beta coefficients allowed to provide the relative "contribution" of factors (d_i) in function's variability. In particular, variability associated with the *i*-th factor, considered to be equal proportion to the square of the corresponding beta coefficient from the total of all squares "beta coefficients" (formula 15)

$$d_i = \frac{\beta_i^2}{\sum_{i=1}^{m} \beta_i^2} 100\% \quad (15)$$

For intermediate calculations used package Excel MS Office. The main part of mathematical processing performed on a personal computer using a standard statistical package STATISTICA 10.0.

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

Results and discussion. To determine the functional capacity of the secondary school age children a significant interest represented by the investigation of functional status and the development of basic physical qualities of the secondary school age children with the presence and absence of chronic somatic diseases.

Studies have shown that students with chronic diseases observed significantly higher percentage of adverse reactions of the cardiovascular system than their healthy peers ($p<0,05$ – $p<0,001$):

— the pupils without chronic diseases (22,22 ± 4,00)% heart rate and (24,07 ± 4,11)% *MVBC* indicators varied inadequate dosed strength exercises, pupils with chronic diseases (67,15 ± 2,84)% *HR* responses and (64,96 ± 2,88)% *MVBC* reactions were disproportionate to the load ($p<0,001$);

— among the healthy children the number of bad *IQR* was almost 7 times lower than that pupils with chronic illnesses (respectively, (2,78 ± 1,58)% and (20,44 ± 2,44)%; $p<0,001$);

— unlike the healthy, schoolchildren with chronic diseases had a higher percentage of hypotonic dystonic reactions and cardiovascular system (respectively, (8,33 ± 2,65)% and (16,79 ± 2,58)%; $p<0,05$);

The study of integral characteristics of the functional state of the secondary school age children also indicated a higher than healthy pupils, the proportion of unfavorable performance of the pupils with chronic illnesses who observed: more low and lower the average of *DPI* (respectively, (63,50 ± 2,91)% and (40,74 ± 4,73)%; $p<0,001$); more unsatisfactory *AP* values (respectively, (52,55 ± 3,02)% and (19,44 ± 3,81)%; $p<0,001$); more low and lower than the average *PhCI* (respectively, (47,45 ± 3,02)% and (30,56 ± 4,43)%; $p<0,01$).

In general we can say that the presence of an average school age chronic somatic diseases is reflected in the higher than in healthy pupils, the level of adverse functional characteristics and the negative character of adaptation processes.

On the basis of a comprehensive evaluation of the results of motor tests also revealed differences between the level of achievements of the pupils' physical training with the presence and absence of chronic diseases. For example, among the pupils with chronic diseases (65,10 ± 3,44)% attained only primary and secondary levels of achievements at Physical Culture (respectively (19,79 ± 2,88)% and (45,31 ± 3,59)%), and sufficient and high levels were (34,90 ± 4,44)% of pupils (respectively (29,69 ± 3,30)% and (5,21 ± 1,60)%). Unlike patients, among the children without chronic diseases, the primary and secondary levels of achievements at Physical Culture have (27,95 ± 3,54)% (respectively, (8,70 ± 2,22)% and (19,25 ± 3,11)%), while in (72,05 ± 3,54)% of pupils indicated sufficient and high levels of achievements (respectively, (58,39 ± 3,88)% and (13,66 ± 2,71)%) ($p<0,001$). So, it turns out that the key to the requirements of the physical fitness control tests is a higher health level of those pupils who did them.

Thus, reduced functionality and adaptive capabilities of children with chronic illnesses do not allow them to cope with physical activity at the level with healthy pupils.

Based on the data presented above were defined most valid markers of the relative risk developing chronic somatic diseases of the secondary school age pupils: low functionality of the circulatory system – bad *IQR* (*RR* = 4,42; 3,94-4,89), inadequate physical load changes in heart rate (*RR* = 4,86; 4,37-5,34) and *MVBC* (*RR* = 3,99; 4,48-4,50); indicators of poor adaptation and failure of adaptation *AP* (*RR* = 3,41; 2,84-3,97); low and lower than average *PhCI* (*RR* = 2,62; 2,13-3,11), insufficient physical preparedness (*RR* = 4,66; 4,21-5,12).

Also, studies have shown that on the background of the chronic diseases reduced functionality of the body were the factors of lack physical fitness of pupils, the most valid markers appeared inappropriate age norms dynamometry indices (*RR* = 3,13; 1,56-4,69), delay time breath to breath (Shtange) (*RR* = 2,38; 1,19-3,56) and expiration (Hencha) (*RR* = 2,61; 1,62-3,59), low *RI* (*RR* = 2,93; 1,84-4,02), inadequate increase to the standard physical activity *MVBC* (*RR* = 1,38; 1,10-2,24).

Thereafter, using the above-defined functional parameters and multivariate regression analysis was found what the properties of physical health are most likely to determine the specific number of diseases or conditions of the secondary school age children. The main criteria in the selection of variables in the regression model structure were minimal values of control variables standard error (s), the most significant contribution to the reliability of each of them (p) and high adequacy of the resulting model (F).

Results of regression analysis are presented in table.

So, regression model was created, based on determining the functionality of the organism and the level of physical characteristics allowed to predict the likely number of diseases or conditions in the pupil's middle school age:

$y_1=0.80x_1+0.52x_2-0.24x_3-0.31x_4$; F=209; p<0,001,

where y_1 – the number of diseases or conditions; x_1 – adaptive potential (AP, in. Fr.); x_2 – changes in heart rate after exercises (HR_2 - HR_1, beats/Min.); x_3 – shifts in minute blood circulation volume after exercises ($MVBC_2$ - $MVBC_1$, l); x_4 – physical fitness (PhT, total points).

High adequacy of obtained regression model (F = 209; p<0,001) allows it to use for the likely number of chronic diseases or conditions that serve as a preventive measure aimed at early diagnosis in health disorders who, because of untimely detection, further threatened transition to existing pathology.

Conclusions

1. It is established that the relative risk of developing chronic somatic diseases have students with unsatisfactory performance adaptive capacity (RR = 3,41; 2,84-3,97), double product index (RR = 2,22; 1,77-2,68), physical condition index (RR = 2,62; 2,13-3,11), as indicators of cardiovascular systems for physical activity (RR = 4,42; 3,94-4,89), inadequate heart rate changes (RR = 4,86; 4,37-5,34) and minute volume of blood circulation (RR = 3,99; 4,48-4,50) after standard exercises and lack of physical fitness (RR = 4,66, 4,21-5,12). The most valid lack markers of children's physical fitness are characteristics of cardiorespiratory and muscular systems, namely: inadequate physical activity changes in a minute volume of blood circulation (RR = 1,38; 1,10-2,24), reduced the rates of respiratory index (RR = 2,93; 1,84-4,02), time breath to breath (RR = 2,38; 1,19-3,56) and expiration (RR = 2,61; 1,62-3,59) and dynamometry (RR = 3,13; 1,56-4,69).

2. Proved the existence of the relationship between health, functional abilities of the body and physical preparedness of the secondary school age children indicates the possibility to target both the physical fitness and health of pupils with chronic diseases through increased functionality and adaptive capabilities of their body.

3. The use of synthetic regression model based on the relationship between health and functional abilities and physical fitness will enable children, in a lack of preventive medical examinations, predict possible number of chronic diseases and pathological states of the basic school age pupils.

Acknowledgements. Author express gratitude to the experts of A. Marzeev Institute of Hygiene and Medical Ecology of NAMS of Ukraine, as part of research projects of which this work was done, in particular M.Y. Antomonov (Dr. of Biological Sciences, Prof.), for their consultation assistance.

Conflict of Interest. None declared.

Table

Contributions indicators in the structure of the resulting mathematical model

Indicators	Statistical characteristics			Contribution d (%)
	b	s	p	
AP	0,758	0,116	<0,001	60,11
HR_2 - HR_1	0,033	0,005	<0,001	25,69
PhT	-0,229	0,059	<0,001	8,94
$MVBC_2$ - $MVBC_1$	-0,105	0,021	<0,001	5,26

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Надійшла до редакції 12.01.2017