UDC 613.955 **O. D. Svietlova**

SYNTHESIZING OF DISCRIMINANT MODELS TO ASSESS THE HEALTH OF CHILDREN DEPENDING ON MORPHOFUNCTIONAL PARAMETERS OF BODY

Introduction. *The analysis of the children's health state shows that the age distribution of the most rapid growth in health violations observed in the average school age. Thus, in this period the depth preventive medical examination is only for children 11 and 14 years, other pupils are deprived of such opportunity which makes it impossible to establish diagnoses in time and their corresponding correction of health.*

Purpose. *The aim of the present study was to find a method of determining the presence of chronic somatic diseases of children by functional indicators of the organism.*

Methods. *Comparison of the functional indicators in children with the presence and absence of chronic somatic diseases with the presence and absence of chronic somatic diseases 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). For the prediction of the chronic physical illnesses presence for pupils, we used discriminant analysis.*

Results. *Proved that there is a close relationship between health and functional abilities of the children: physical condition index ($\chi^2 = 12,21$; $p < 0,001$), adaptive potential ($\chi^2 = 19,69$; $p < 0,001$), double product index ($\chi^2 = 15,27$; $p < 0,001$), changes to the standard exercises of heart rate and minute volume of blood circulation (respectively, $\chi^2 = 44,39$, $p < 0,001$; $\chi^2 = 30,26$, $p < 0,001$). After were found valid integrated features of pupil's functional state, most informative indicative of the health of children. Are based on these functional parameters the classification functions have quite high specificity (84,93 – 90,99%) and sensitivity (75,76 – 80,56 %). Adequacy of mathematical models significant ($F = 11,06 – 22,54$) at the level $p < 0,001$.*

Originality. *The method of identifying children at "risk" appearance of chronic somatic diseases only functional parameters of the body.*

Conclusion. *In the absence of annual preventive medical examinations in terms of secondary schools, the use of the proposed classification functions help to find the detection of disease.*

Propositions. *The application submitted classification functions will help of planning health measures, which are suspend not to increase the incidence of the younger generation.*

Key words: *schoolchildren, middle school age, health status, functional status, mathematical model, illness.*

Formulation of the problem. According to the Order of Ministry of Health in Ukraine, number 682 "On improvement of health care for pupils of secondary schools" from 16.08.2010., of the secondary school age students the depth preventive medical examination is only for children 11 and 14 years. Other pupils are deprived of such opportunity which makes it impossible to establish diagnoses intime and their corresponding correction of health. Therefore, given the serious situation from deteriorating health of modern school-age children, particular attention needs thorough studying of health-care younger generation.

Analysis of the latest publications. In recent decades, in Ukraine marked deterioration of pupils' health: the growing number of chronic diseases and morpho-functional disorders, a combination of several diseases, age-dependent pathology formation of a younger age [1 – 3]. From junior to high school increases the proportion of pupils with different morphofunctional deviations and a formed chronic disease. The age distribution of pupils shows that the most rapid growth in health violations observed in the average school age [4 – 5].

According to the "Annual report on the state of health, sanitary and epidemiological situation and the results of activity of the health care system in Ukraine 2015" deterioration of

living conditions and reduce stability in society cause an increase stress conditions in adolescents to a greater extent than in other age groups, which leads to an increase incidence in them. Also, it is in adolescence, often appears the realization of a genetic predisposition to pathological abnormalities [6]. Therefore, it is in this age period requires careful preventive supervision of health. Because, the earlier will be carried out the necessary diagnostic testing of physical condition of adolescent, the more effective will be the process of recovery.

At the same time important to note the significance of early diagnosis and early prevention of deviations in the health. It is known that early detection of the disease helps avoid complications, promotes faster recovery and prevents the transition of the disease in chronic form [7 – 9]. Therefore, according to the current Order of Ministry of Health of Ukraine № 682, in the average school age depth preventive medical examination conducted only in 11 and 14 years, it is important to lead in rapid diagnosis of health for students of other ages.

The aim of the study was to find identical depth medical examination approach to assessing of the children's health by functional parameters of basic physiological systems.

To achieve this goal it was necessary to solve the following problems:

1) to explore the features of the functional state of the secondary school age students with the presence and absence of chronic somatic diseases;

2) based on the data, to find an adequate approach to assessing of the children's health by functional indicators to identify the "risk" persons of chronic physical illness' occurrence.

Materials and methods

We used medical, biological and mathematical methods.

In the study involved 382 middle school age pupils, including 274 pupils who had a history of chronic physical disease and were referred to the preparatory and were attributed to the third health group and 108 pupils without disabilities in health.

For a detailed studying of the children's health the functional parameters of the cardiorespiratory system and integrated indicators are used that combine the results of morphological and physiological research.

To assess the functional state of the cardiovascular system was used Martin test with dosed physical activity as 20 sit-ups in 30 seconds, measured parameters of heart rate and blood pressure before and after the exercise.

The percentage increase of heart rate and pulse pressure (due to dosed physical load) was determined by comparing the data before loading and after (formula 1, 2):

$$HRpl. = \frac{(HR_2 - \mathrm{HR}_1)}{HR_1} \times 100\% \quad (1)$$

$$PPpl. = \frac{(PP_2 - PP_1)}{PP_1} \times 100\% \quad (2)$$

where: *HRpl.* – increasing of heart rate after dosed physical load (%); *PPpl.* – increasing in pulse pressure after dosed physical load (%); HR_1 – heart rate before the load (beats / Min.); HR_2 – heart rate after the load (beats / Min.); PP_1 – pulse pressure before the load (mm Hg. In.); PP_2 – pulse pressure after the load (mm Hg. In.).

During the evaluation of the functional state of the respiratory system were used absolute figures and their value as a percentage relative to appropriate individual settings (in fact, at one and the same calendar age, children have different indicators of total body size). The value of life index (*LI*) – the deviation of actual vital lung capacity (vital lung capacity, measured by dry portable spirometer) of appropriate one was determined by the following formula 3:

$$LI = \frac{VLC}{PVLC} \times 100\% \quad (3)$$

where: *LI* - living index (%) *VLC* – vital lung capacity (l); *PVLC* – proper lung capacity (l). The proper vital lung capacity (*PVLC*) was calculated individually for each child:

- for boys who have a body length 1,0-1,65 m (formula 4)

$$PVLC = 1{,}53 \times BL - 3{,}9; \quad (4)$$

- for boys who have a body length of more than 1,65m (formula 5)

$$PVLC = 10 \times BL - 12{,}85; \quad (5)$$

- for girls (formula 6)

$$PVLC = 3{,}75 \times BL - 3{,}15 \quad (6)$$

where: *PVLC* proper vital lung capacity (l); *BL* – body length (m).

Adaptation potential (*AP*) was determined by the formula of Baevskyi, Bersenyeva (formula 7):

$$AP = 0{,}011 \times HR + 0{,}014 \times SBP + 0{,}008 \times DBP + 0{,}014 \times A + 0{,}009 \times BW - (0{,}009 \times BL + 0{,}27) \quad (7)$$

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).

Physical condition index (*PhCI*) was calculated by the Pirogova's formula 8:

$$PhCI = \frac{700 - 3 \times HR - 2{,}5 \times ADP - 2{,}7 \times A + 0{,}28 \times BW}{350 - 2{,}6 \times A + 0{,}21 \times BL} \quad (8)$$

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 (9):

$$ADP = \frac{PP}{3} + DBP \quad (9)$$

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

Vegetative Index (*VI*) is determined by the formula 10:

$$VI = \frac{DBP}{HR} \quad (10)$$

where: *VI* – vegetative index (in. Fr.); *DBP* – diastolic blood pressure (mm Hg. In.); *HR* – heart rate (beats / Min.).

Using discriminant analysis, the classification functions were developed for the prediction of the chronic physical illnesses presence for pupils of secondary school age. The result measured: the adequacy of the obtained mathematical models (the criterion *F* and significance level of *p*); the significance of the effect of individual factors on binary result (the large *p*); specificity and sensitivity obtained predictive models.

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 5.0.

Results and discussion

The researches were based on certain relationships between the presence / absence of chronic diseases on the one hand and functional parameters of the child on the other. In particular, a close relationship between health and physical condition index was identified (*PhCI* $\chi^2 = 12{,}21$; $p < 0{,}001$), adaptive potential (*AP* $\chi^2 = 19{,}69$; $p < 0{,}001$), efficiency of the cardiovascular system (double product index or Robinson – *DPI* $\chi^2 = 15{,}27$; $p < 0{,}001$) and its reactivity (changes to the standard exercises of heart rate – *HR* and minute volume of blood circulation – *MVBC* (respectively, $\chi^2 = 44{,}39$, $p < 0{,}001$; $\chi^2 = 30{,}26$, $p < 0{,}001$).

In further studies were found most informative integrated features of pupil's functional state from the presence and absence of chronic physical illnesses which arose as: adaptive potential (*AP*), which reflects the adaptation and adaptive reactions of the whole organism; physical condition index (*PhCI*), which describes the physical condition of the child; vegetative index (*VI*), which is used for evaluation of autonomic nervous system; living index (*LI*), which evaluated the functionality of the respiratory system; percent of heart rate increasing (*HR*) and pulse pressure (*PP*) after physical load (in the form of 20 sit-ups in 30 s), which reflects the adequacy of the response of the cardiovascular system to the dosed load, helping to identify the hidden disorders of the circulatory functioning system that due compensation mechanisms are not detected.

Thereafter, using discriminant analysis, the classification functions were developed for the prediction of the chronic physical illnesses presence for pupils of secondary school age, that in the absence of annual preventive medical examinations, promote early diagnosis of diseases. The obtained classification functions were as follows:

– for pupils of 11-12 years (specificity – 90,99 %, sensitivity – 75,76 %; $F = 22{,}54$; $p < 0{,}001$)

$$y_1 = -921{,}08 + 0{,}12x_1 - 423{,}32x_2 + 0{,}48x_3 + 736{,}36x_4 + 1612{,}12x_5 - 0{,}94x_6,$$

$$y_2 = -901{,}79 + 0{,}0002x_1 - 411{,}52x_2 + 0{,}48x_3 + 722{,}53x_4 + 1584{,}39x_5 - 0{,}75x_6;$$

– for pupils of 13-14 years (specificity – 84,93 %, sensitivity – 80,56 %; $F = 11{,}06$; $p < 0{,}001$)

$$y_1 = -739{,}13 + 0{,}52x_1 - 281{,}44x_2 + 0{,}79x_3 + 572{,}69x_4 + 1220{,}46x_5 - 0{,}90x_6,$$

$$y_2 = -724{,}09 + 0{,}41x_1 - 275{,}26x_2 + 0{,}83x_3 + 562{,}88x_4 + 1196{,}97x_5 - 0{,}74x_6,$$

where: y_1 – the assessment of the likely presence of chronic diseases; y_2 – the assessment of the likely absence of chronic diseases; x_1 – *HRpl.* (%); x_2 – *VI* (in. Fr.); x_3 – *PPpl.* (%); x_4 – *AP* (in. Fr.); x_5 – *PhCI* (in. Fr.) x_6 – *LI* (%).

These features allow classification to calculate the probability of chronic illnesses to receive individual and the values of y_1 and y_2, namely:

$$p^{+cd} = \frac{y_1}{y_1 + y_2} \times 100\%,$$

$$p^{-cd} \frac{y_2}{y_1 + y_2} \times 100\%,$$

where: p^{+cd} – to receive the reliability of chronic disease (%); p^{-cd} – the likely absence of chronic disease (%).

The specificity and sensitivity obtained classification functions were quite high (respectively, 84,93 – 90,99 % and 75,76 – 80,56 %) adequacy of mathematical models

significant (F = 11,06 – 22,54) at the level (p < 0,001), which allows with the high-probability forecast to apply classification functions in practice.

For example, an 11-year girl has the following morphological characteristics: body length – 1,40 m; body weight – 35 kg; heart rate before the physical load – 100 beats / Min.; systolic blood pressure before the physical load – 87 mm Hg. In.; dyastolichnyy blood pressure before the physical load – 56 mm Hg. In.; heart rate after the load – 140 beats / Min.; systolic blood pressure after the load – 111 mm Hg. In.; dyastolichnyy blood pressure after the load – 65 mm Hg. In.; vital lung capacity – 1,10 l.

As a result of calculations according to formulas presented above, we get the following values: *HRpl.* – 40 %; *VI* – 0,87 in. Fr.; *PPpl.* – 48,39 %; *AP* –1,71 in. Fr.; *PhCI* – 0,611 in. Fr.; *LI* – 52,38 %.

Substitute obtained classification parameters in functions:

$$У_1=-921,08+0,12\times40-423,32\times0,87+0,48\times48,39+736,36\times1,71+1612,12\times0,611-0,94\times52,38=929,59$$

$$У_2=-901,79+0,0002\times40-411,52\times0,87+0,48\times48,39+722,53\times1,71+1584,39\times0,611-0,75\times52,38=904,40$$

Calculate the probability of the chronic disease presence in the value of y_1 and y_2:

$$p^{+cd}=929,59/(929,59+904,40)\times100=50,69\ \%$$

$$p^{-cd}=904,40/(929,59+904,40)\times100=49,31\ \%$$

Calculations showed that the result of probable presence of chronic disease (p^{+cd}) is greater than the probable absence of disease (p^{-cd}), so a girl we are examined relates to the risk of chronic physical illnes and therefore require additional depth survey of experts in terms of health-care setting.

We understand the conditionality of the evaluation of children's health but this method will tentatively identify deviations that might not yet have an organic basis in the form of severe structural damage, but as the absence of annual preventive medical examinations will help to draw attention to the likely problems and provide perspective correction functional state of resources and adaptation of pupils.

Conclusions

1. Based on the conducted studies it was confirmed that there is a link between health and functional abilities of the secondary school age children.
2. On the basis of morphological and functional characteristics of children with different state of health a method of determining the possible presence of chronic somatic diseases of students of the secondary school age was developed.
3. Using the proposed classification functions built on the relationship functioning of the basic physiological systems of health will help to detect the diseases of children in time and as a result to plan the preventive health measures to suspend the increase of the incidence of young generation.

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Анотація. Свєтлова О. Д. Синтезування дискримінантних моделей для оцінки стану здоров'я дітей в залежності від морфофункціональних параметрів організму

Вступ. *Аналіз стану здоров'я школярів показує, що найбільш стрімке зростання порушень здоров'я відмічається саме в середньому шкільному віці. При цьому, в даному віковому періоді поглибленому профілактичному медичному огляду підлягають лише діти 11 та 14 років, інші школярі позбавлені такої можливості, що робить неможливим своєчасне встановлення діагнозів і, відповідно, вчасну корекцію стану здоров'я.*

Мета. *Віднайти спосіб визначення наявності хронічних соматичних захворювань у дітей за функціональними параметрами їх організму.*

Методи. *Порівняння функціональних показників у дітей із наявністю та відсутністю хронічнних соматичних захворювань проводилися з використанням t-критерію Стьюдента. Значення вважалися статистично достовірними при $p < 0,05$. Для номінальних змінних взаємозв'язок визначався за таблицями спряженості за допомогою критерія χ^2-Пірсона. Для прогнозу наявності хронічних соматичних захворювань в учнів використовувався дискримінантний аналіз.*

Результати. *Доведено існування тісного взаємозв'язку між станом здоров'я та функціональними можливостями дітей: індексом фізичного стану ($\chi^2=12,21$; $p<0,001$),*

адаптаційним потенціалом (χ^2=19,69; p<0,001), індексом подвійного добутку (χ^2=15,27; p<0,001), зрушеннями на стандартне фізичне навантаження показників частоти серцевих скорочень і хвилинного об'єму кровообігу (відповідно, χ^2=44,39, p<0,001; χ^2=30,26, p<0,001). Надалі були визначені валідні характеристики функціонального стану, які найбільш інформативно свідчили про стан здоров'я дітей. Побудовані на основі цих функціональних параметрів класифікаційні функції мали досить високі специфічність (84,93 – 90,99 %) та чутливість (75,76 – 80,56 %). Адекватність отриманих моделей значима (F = 11,06 – 22,54) на рівні p < 0,001.

***Новизна.** Запропоновано методику виявлення дітей з групи "ризику" появи хронічних соматичних захворювань, лише за функціональними параметрами організму.*

***Висновок.** За умови відсутності щорічних профілактичних медичних оглядів в умовах загальноосвітніх навчальних закладів, використання запропонованих класифікаційних функцій допоможе своєчасному виявленню патології у дітей.*

***Пропозиції.** Застосування представлених класифікаційних функцій сприятиме плануванню оздоровчих заходів, спрямованих на призупинення зростання захворюваності підростаючого покоління.*

***Ключові слова:** школярі, середній шкільний вік, стан здоров'я, функціональний стан, математична модель, хвороби.*

Черкаський національний університет імені Богдана Хмельницького

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