

Physical development and functional state of the neuromuscular apparatus of students of different health groups

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Abstract:

Purpose. To determine the strength of the relationship between the body mass index and the functional state of the neuromuscular apparatus of students with different levels of somatic health in order to correct the educational process in physical education classes. **Materials and methods.** The study involved 216 students of the Medical University of Nizhny Novgorod (Russia) aged 19.6 ± 1.4 years. Of these, 101 male students took part in the study, namely, 59 of them had a basic medical group, and 42 people had a preparatory medical group for physical culture and sports, and 115 female students, of which 71 people had a basic medical group, and 44 people have a preparatory group. To determine height and weight indicators, as well as body mass index, a certified height meter with floor scales was used. We correlated the obtained data with the gradation of body mass index according to the recommendations of the World Health Organization. The state of the neuromuscular apparatus was assessed using two tests: the tapping test and the accuracy of muscle efforts. The tapping test was carried out according to the standard method. The strength assessment was determined by the method of carpal dynamometry with the calculation of absolute and relative strength indices. In addition, the accuracy of muscle efforts was monitored and correlated with a standardized scale for interpreting the results. To determine the relationship between body mass index and the state of the neuromuscular apparatus, the correlation coefficient was used. **Results.** It was found that among the male representatives of the preparatory group, the body mass index approaches the state of obesity. In the study of the coefficient of strength of the nervous system, an average type is observed in all representatives of the student youth, however, in the girls of the main group, there is a tendency to shift towards a strong type of the nervous system, especially for the right hand, and a more pronounced increase in the coefficient of functional asymmetry was recorded in the boys of the preparatory group. According to the values of absolute and relative strength indicators of the hands of both hands, significantly low strength characteristics were recorded in boys and girls of the preparatory group. The accuracy of muscle efforts shows a higher adaptability in the performance of the test among the students of the main group. **Conclusions.** Correlation analysis demonstrated a relationship between an increase in body mass index and a tendency to a weak type of nervous system, as well as a certain increase in strength indicators and a decrease in the accuracy of their reproduction with various muscle efforts in the absence of visual control.

Key Words: physical development, physical education, body mass index (BMI), neuromuscular system, adaptation

Introduction

One of the important indicators of the state of well-being of a society is the level of health of children, adolescents and young people (Rueggsegger, & Booth, 2018). Often occurring socio-economic turbulence in the society of modern people, profound changes in the body associated with the effects of acceleration and retardation (Sattarov, & Karelina, 2018) can affect not only human health, but also the anthropometric and functional parameters of his body, especially this may manifest itself in adolescence (Eksterowicz, & Napierała, 2020). An objective integral indicator of the state of health and harmonious balance in the work of all systems of the human body is its physical development (Luo et.al., 2018). It is a criterion for the state of human metabolic,

endocrine, immune and other biological processes. It is known that unfavorable sociobiological factors can significantly worsen physical development, making it disharmonic (Zhang et al., 2019; Zurita-Ortega et al., 2019). The impact on the child's body of negative environmental factors begins to manifest itself at school age (Krasnozhan, 2017). Further vocational training may continue to negatively impact students' health (Glazkova et al., 2020). Therefore, some researchers recommend that student youth be classified as a risk group for health reasons (Yu-Xiang et al., 2018). By the time they graduate from university, only a quarter of graduates can be considered practically healthy (Meermanova et al., 2017). These data indicate the need for specialists from various sciences to study the issue of the health status of students (Momot et al., 2020).

Modern education at universities is characterized by an increase in digital learning, significant in intensity and volume of educational and psycho-emotional stress among students. One of the triggers of this process is inactivity, the presence of bad habits at the same time as the lack of a rational diet, the functioning of the body at the limit of its capabilities (Gerber et al., 2017; Eksterowicz, & Napierała, 2020). The decline in human health is caused by the above-mentioned mechanisms that contribute to a significant strain in ensuring the homeostatic functions of the body (Hayano et al., 2019; Christiani et al., 2021).

The decline in the quality of health among modern students is manifested in a dynamic increase in the complexity of teaching physical culture in educational institutions of higher education (Gerber et al. 2017; Glazkov et al., 2020). In the process of implementing the discipline of physical education, one should pay attention to the study of various factors that may affect the effectiveness of the educational process (Limorenko, 2022). Differences in morphofunctional indicators of students, as well as somatic and physical health, in particular, relate to the above factors (Bocharin et al., 2023). When studying the morphofunctional status, the main indicator of the physical development of an individual is body weight, which acts as an integral indicator of the level of various processes occurring in the body (Lee, 2008). To characterize the state of weight, the ratio of length and body weight is used, this is called the body mass index (Bocharin, & Guryanov, 2023; Jha et al., 2021). According to the materials of George et al. (2023), there is a direct relationship between the quality of physical fitness and the physiological characteristics of the nervous system, which is manifested in the adaptive reactions of the body. In particular, the tapping test is widely used to determine the properties of the nervous system (mobility, lability, strength) (Nopin, 2022), Chaabouni et al. (2022). A necessary point for assessing the neuromuscular apparatus of a person is the assessment of the accuracy of muscle efforts, which is carried out using a hand dynamometer. The result obtained acts as a criterion of fitness, which depends on the state of the volitional sphere of the individual, the level of his physical fitness and functional state (Baiguzhina et al., 2020). Despite the available scientific data on these issues, it remains relevant to study the relationship of these parameters with each other, taking into account the body mass index of students with different states of somatic health. The study of these issues, in our opinion, will make it possible to perform a correction in the educational programs of physical education, taking into account the health of students, which will increase the health trend of physical culture.

Purpose. To study the possibilities of substantiating a personalized approach to physical education of students with different levels of somatic health by determining the strength of the relationship between the body mass index and the functional state of their neuromuscular apparatus.

Material & methods

The study involved 216 students aged 19.6 ± 1.4 years who studied at the Medical University of Nizhny Novgorod (Russia). Of the surveyed, there were 101 male students (59 people had the main medical group for physical culture and sports, 42 people had a preparatory medical group) and 115 female students (71 people had the main medical group for physical culture and sports, 44 people - preparatory medical group). All the students examined before participating in the experiment signed an informed voluntary consent and could at any time refuse to continue participating in it, which is fully consistent with the Declaration of Helsinki 2008.

We calculated the representativeness of the sample using the formula: $n = \frac{t^2}{k \cdot \Delta}$, where n is the size of the sample, t is the probability that the specified degree of inaccuracy will indeed not be exceeded, k is the coefficient taking into account the degree of responsibility of the work performed is 0.3 (Bocharin, & Guryanov, 2023). The study was carried out in the morning hours in a quiet, well-ventilated room with a constant temperature from $+20$ to $+22$ $^{\circ}\text{C}$, and before it began, the subjects were given time to relax. To determine the length and weight of the body, we used a stadiometer with floor scales VMEN-200-50/100-D1-A (Russia). This device is able to automatically calculate the body mass index (BMI), on the basis of which the assessment of deficiency or excess body weight was carried out, in accordance with the gradation of body mass index indicators according to the recommendations of the World Health Organization (WHO Global Database on Body Mass Index (BMI), 2012).

The state of the neuromuscular apparatus was assessed using two functional tests: the tapping test and the accuracy of muscle efforts. The tapping test was carried out using standard forms with 6 squares drawn on them (Nopin et al., 2022). On a signal, the subject should put dots in the square at the fastest possible pace, and the transition to the next square was carried out only on command (at intervals of 5 seconds), in a certain sequence and without interrupting work. To process the results, the number of points in each square was counted

and then the dynamics of the maximum rate of hand movement was determined. To assess the strength of nervous processes, the *coefficient of strength of nervous system* (CSNS, arbitrary units) was calculated for each hand, and the *coefficient of functional asymmetry* (CFA, %) was also determined. To study the power indices, the absolute force (kg) was determined using a hand dynamometer DMER-120 (Russia) with the calculation of the relative power index, %. A muscle effort accuracy test was also used. During the first attempt, the subject squeezed the dynamometer with maximum effort, and during the second attempt, with half of the maximum effort, without visual control over the device indicators.

The value of deviations from the set value (in %) *muscle effort accuracy* (MEA) was calculated by the formula: $MEA = [(ME_1:2 - ME_2) \times 100\%]$, where ME_1 is the first muscle effort, ME_2 is the second muscle effort. Muscle effort accuracy was assessed on a five-point scale in accordance with the standardized scale (Mandrikov, & Mitsulina, 2006), Table 1.

Table 1. Scale for assessing the accuracy of muscle efforts

Evaluation, points	Indicators, %	
	Youths	female students
«5»	0-6.6	0-4.3
«4»	6.7-15.3	4.4-15.9
«3»	15.4-33.0	16.0-39.0
«2»	33.1-41.8	39.1-50.6
«1»	41.9 and higher	50.7 and higher

Data processing took place using the method of variational statistics using the software packages Statistica 10.1 for Windows and Microsoft Excel 2016. The arithmetic mean (M), standard deviation (σ) and standard error of the mean (m) were calculated for each sample. The obtained data were checked for the normality of the distribution using the Kolmogorov-Smirnov criterion with the Lillifors correction. When comparing the subjects by gender and medical group, one-factor analysis of variance ANOVA was chosen as a criterion. The relationship between the body mass index and the state of the neuromuscular apparatus was

assessed using the Pearson correlation criterion (r) using the formula $p_{x,y} = \frac{\text{Cov}(X,Y)}{\sigma_1 \times \sigma_2}$, and the level of statistical significance of the obtained correlation was checked by the Student's criterion coefficient $t = \frac{r}{m}$, where m is interpreted as a correlation error. Differences were considered significant at $p \leq 0.05$.

Results

The values of anthropometry, tapping test and dynamometry of the hands in male and female students of different health groups are presented in Table 2.

Table 2. Features of physical development and the state of the neuromuscular system in students of different health groups, $M \pm m$

Показатель	Male students		Female students	
	Medical group			
	main medical group (n=59)	preparatory medical group (n=42)	main medical group (n=71)	preparatory medical group (n=44)
Body length, cm	178.5±2.4	183.5±2.6*	167.1±2.2	163.5±2.3 [#]
Body weight, kg	74.6±2.2	81.1±3.5*	60.6±1.5	64.9±2.3 [#]
Body mass index, kg/m2	22.9±1.1	24.1±1.9*	22.1±1.7	22.8±1.1
CSNS for the right hand, arb. units	+10.4±0.13	+7.8±0.26*	+9.5±0.12	+7.2±0.23 [#]
CSNS for the left hand, arb. units	+9.2±0.23	+6.3±0.18*	+6.3±0.26	+5.9±0.32 [#]
CFA, %	17.3±0.28	24.7±0.36*	16.4±0.42	22.8±0.37 [#]
Dynamometry of the right hand, kg	45.6±0.35	42.6±0.18*	25.7±0.19	23.4±0.32 [#]
Dynamometry of the left hand, kg	44.5±0.28	41.6±0.26*	24.8±0.21	21.9±0.29 [#]
Power index, %	60.5	51.8	41.5	34.7

Note: "*" - the indicators are statistically significant among the boys of the main and preparatory groups ($p < 0.05$); "[#]" - indicators are statistically significant among girls of the main and preparatory groups ($p < 0.05$)

Statistically significant differences were established in terms of body length and weight both among male students of different health groups and among female students. Body length and body weight in the representatives of our preparatory group were 2.8 and 8.7% higher than in the boys of the main group, respectively, $p \leq 0.05$, the length and weight of the body were 2.2 and 7.1% higher, respectively, compared with the female students of the main group, $p \leq 0.05$.

Only male students showed statistically significant differences in BMI, while in the preparatory group it was higher by 5.2%, which corresponded to the state of pre-obesity ($p < 0.05$).

Female students of different health groups do not have statistical significance in the above indicator. In professional athletes, simultaneously with the determination of BMI, the central obesity index is evaluated to prevent the phenomenon of overweight. However, all the subjects are students who, apart from physical education, do not engage in any other physical activity.

Analysis of the results of the tapping test in Table 2 is presented as the result of calculating the coefficient of strength of the nervous system (CSNS). The calculation of this indicator was carried out according to the formula, taking into account difference in the sums of counting points in each square and in the first square. The interpretation of the results was carried out by calculating the coefficients with negative or positive signs, characterizing the strength of the nervous system. A strong type of nervous system was observed for the right hand in the boys of the main group, and the average type - for the left hand of the same group of subjects. We noted the same type in the boys of the preparatory group for both hands, as well as in the students of the main and preparatory groups. I would like to note that in the representatives of the main group, the strength coefficient of nervous processes approaches +10 (this is more significant for the right hand), which characterizes their tendency to shift the characteristics of the type of nervous system of the strong type. It is impossible not to note the dominance of the right hand among almost all the subjects.

According to the observation of the coefficient of functional asymmetry (CFA), an increase in the imbalance of the nature of symmetry was found in all subjects of the preparatory group, in comparison with the main group of students, $p < 0.05$.

According to the results of the dynamometry test, the predominance of a high level of strength abilities among students of the main group was established, $p < 0.05$. This is manifested in the parameters of the absolute strength of both hands, where in boys they were 7.0 and 6.5% higher than the students of the preparatory group, and in girls - by 9.4 and 11.7%, respectively, $p < 0.05$. The same dynamics was recorded when assessing the strength index value.

Then, the accuracy of muscle efforts was assessed on the basis of carpal dynamometry. To determine this parameter, the students made two attempts: first, they compressed the dynamometer with maximum force, and then - half of the first attempt, without visual control of the device reading, Figure 1.

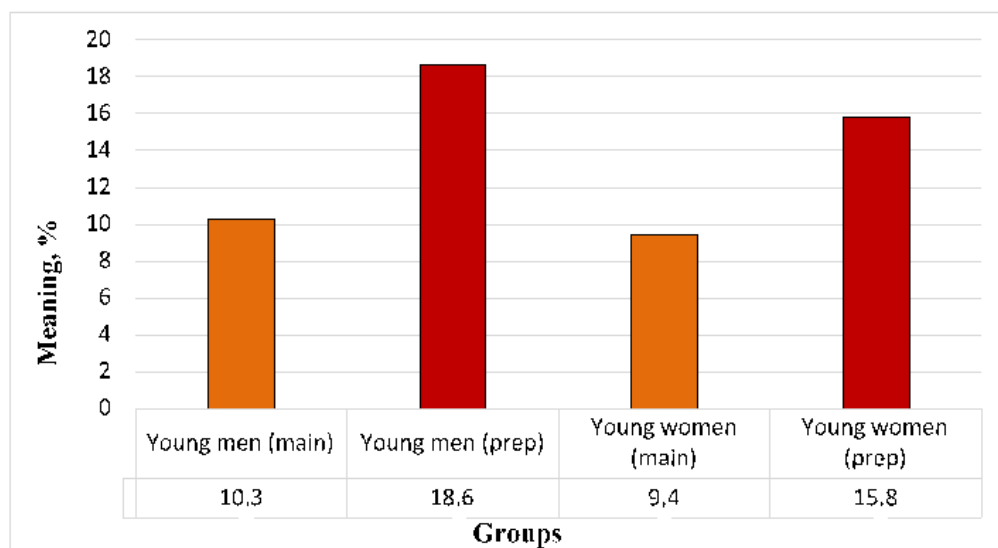


Fig. 1. Accuracy of muscle efforts in students of different health groups

The indicator of the accuracy of muscle efforts allowed us to establish that differentiation without visual control was worse in students of the preparatory group. For example, this parameter was determined in the value of 10.3%, in the students of the main group, and it differs from the boys of the preparatory group by 80.6% in an upward direction. Among the female students of the main group of MEA was 9.4%, which is 68.1% better than among the students of the preparatory group. These data indicate that the skeletal muscle control system turned out to be more adapted in students in the main health group and informs about the specificity of the adaptation of the muscular system to this functional test.

Correlation analysis (Fig. 2) shows that the BMI index has an inverse correlation with the strength coefficient of the nervous system ($r = 0.21$, $p < 0.05$) and a positive relationship with the coefficient of functional asymmetry ($r = 0.41$, $p < 0.05$).

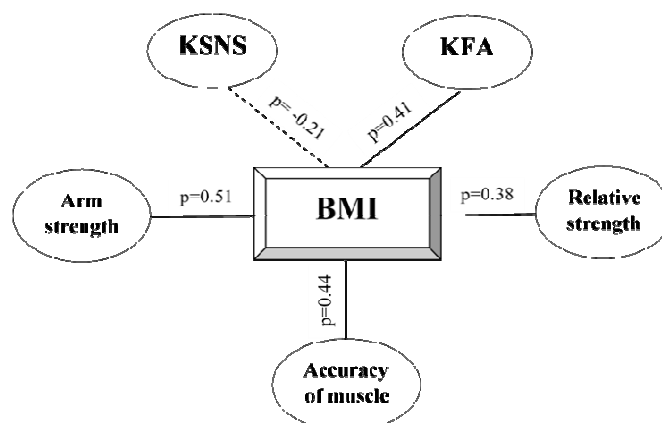


Fig. 2. Correlation of BMI with coefficients of nervous system strength, functional asymmetry, absolute and relative hand strength, and muscular effort accuracy

When analyzing relationships with the muscular system, it was found that BMI has direct correlations with carpal dynamometry ($r=0.51$, $p=0.05$), strength index ($r=0.38$, $p=0.05$) and muscle effort accuracy ($r=0.44$, $p=0.05$). It can be assumed that an increase in the ratio of body length to body weight can affect the strength indicators of carpal dynamometry, while increasing the spread in the accuracy of values when using dynamometry without visual control. The established relationship between BMI and the parameters of strength and endurance of the nervous system is confirmed by the tendency to a weak type of nervous system in conditions of increasing body weight, as well as a shift in the coefficient of asymmetry towards the mismatch of the functions of the nervous system in the tapping test.

Dicussion

In the study of weight and height anthropometric indicators, body mass index is very popular among researchers, due to the simplicity and accessibility of measurements (Bocharin, & Guryanov, 2023; Kolokoltsev et al., 2023). In conjunction with this method, testing of power indices is used as the physical qualities of a person, including those studying at universities. Wrist dynamometry can be used as an instrumental approach to studying the strength of skeletal muscles, which makes it possible to evaluate both absolute indicators of the muscular system and indicators of relative strength, as well as the accuracy of muscle efforts. This allows you to objectively study the strength preparedness of students and correlate the obtained indicators with anthropometric data (Lee, & Gallagher, 2008). In addition, it seems relevant to monitor psychomotor functions to ensure effective control of movements, which is a multilevel process of performing a motor task, implemented in the form of a tapping test (Baiguzhina et al., 2020).

Statistically significant differences in body length and body weight are observed among students of different health groups. At the same time, these differences for BMI are established only for male students. Among the young men of the main group, a strong type of nervous system for the right hand and an average type for the left hand prevailed according to the results of calculating the strength coefficient of the nervous system. The same indicator characterized the average type of nervous system in all the girls participating in the experiment. These data do not contradict the results of other researchers (Chaabouni et al., 2022; Georgi et al., 2023).

When calculating the coefficient of functional asymmetry, an increase in this indicator among students of the preparatory group is noted, while it is more pronounced among male students. Increased capabilities in the indicator of absolute wrist strength were demonstrated among boys and girls of the main health group, while, by the nature of relative strength, there was a decrease in strength indicators among students of the preparatory group. In assessing the accuracy of muscle efforts, a higher specificity of adaptation of the muscular system to a functional test was observed in students of the main group. According to the results of the evaluation of the relationships, direct correlations were established between the body mass index, the coefficient of asymmetry of dynamometric tests, the parameters of relative strength and accuracy of muscular efforts. A moderate inverse correlation has been established in the indicators of the body mass index and the strength coefficient of the nervous system. The results of our studies supplemented the materials of the works of other authors and do not contradict their conclusions (Baiguzhina et al., 2020; Jha et al., 2021).

The analysis of functional indicators and BMI of students of different health groups showed the presence of interrelations between them. The data obtained make it possible to comprehensively plan curricula for the implementation of the discipline of physical culture and sports. We believe that making adjustments to the organization of physical education will increase the effectiveness of the health-improving orientation of physical culture at universities.

Conclusions

Monitoring of the body mass index index showed it in the zone of pre-obesity in young men of the preparatory group. Observation of the state of the nervous system demonstrated the presence of an average type of nervous system for almost all subjects, but the students of the main group have a tendency to a strong type for the right hand. A sufficiently pronounced increase in the coefficient of functional asymmetry was noted in the young men of the preparatory group, which characterizes their relative misalignment in the work of the nervous system.

The assessment of strength characteristics showed their decrease in representatives of the preparatory health group. At the same time, the students of the main group have a fairly high level of adaptation according to the results of the test for the accuracy of muscle efforts without visual control. The presence of correlational relationships is demonstrated in body mass index indicators and a tendency to a weak type of nervous system. In addition, a slight increase in the strength of the flexors of the hand corresponds to a decrease in the accuracy of reproduction in the test for the accuracy of muscle effort. We assume that the application of these research results will provide a qualitative approach to the organization of physical education classes and simulate the effectiveness of physical education teaching in universities.

Conflicts of interest. The authors declare no conflict of interest.

References:

- Baiguzhina, O.V., Shaposhnikova, M.V., Komissarova, O.A., Nikolskaya, O.B. (2020). Neurodynamic predictors of precise motor response. *Human Sport Medicine*, 20(S2), 26-30.
- Bocharin, I., Guryanov, M., Romanova, E., Pozdeeva, A., Kolokoltsev, M., Vorozheikin, A., Malkin, A., Poboronchuk, T., Lobastova, R., & Kovalev, A. (2023). Instrumental control of functional indicators in students with health deviation. *Journal of Physical Education and Sport*, 23(5), 1096-1102. DOI:10.7752/jpes.2023.05137.
- Bocharin, I.V., & Guryanov, M.S. (2023). Features of anthropometric indicators of junior students. *Karelian Scientific Journal*, 12(2). Art 43, 5-9. DOI: 10.57145/27129772_2023_12_02_01.
- Chaabouni, S., Methnani, R., Hadabi, B., Busafi, M., Kitani M., Jadidi, K., Samozino, P., Moalla, W., & Gmada, N. (2022). A simple field tapping test for evaluating frequency qualities of the lower limb neuromuscular system in soccer players: A validity and reliability study. *Int J Environ Res Public Health*, 19(7), 3792. DOI: 10.3390/ijerph19073792.
- Christiani, M., Grosicki, G., & Flatt, A. (2021). Cardiac-autonomic and hemodynamic responses to a hypertonic, sugar-sweetened sports beverage in physically active men. *Appl Physiol Nutr Metab*, 24, 1-7. DOI: 10.1139/apnm-2021-0138
- Eksterowicz, Jerzy, & Napierała, Marek (2020). Sexual dimorphism of the selected somatic features of students attending physical education course in Kazimierz Wielki University during the years 2006-2017. *Journal of Physical Education and Sport*, 20 (1), Art 32, 242 - 248, DOI:10.7752/jpes.2020.01032
- Georgi, M., Gingras, B., Zentner, M. (2023). The Tapping-PROMS: A test for the assessment of sensorimotor rhythmic abilities. *Front Psychol*, 13, 862468. DOI: 10.3389/fpsyg.2022.862468.
- Gerber, M., Ludyga, S., Mucke, M., Colledge, F., Brand, S., & Puhse, U. (2017). Low vigorous physical activity is associated with increased adrenocortical reactivity to psychosocial stress in students with high stress perceptions. *Psychoneuroendocrinology*, 80, 104-113. <https://doi.org/10.1016/j.psyneuen.2017.03.004>
- Glazkova, G., Mamonova, O., Gracheva, D., Pukhovskaya, M. (2020). Social aspects of physical education of students with deviations in health status. *Journal of Physical Education and Sport*, 20 (5), Art 347, 2545 - 2553, DOI:10.7752/jpes.2020.05347
- Hayano, J., Yuda, E. Hayano, J., et al. (2019). Pitfalls of assessment of autonomic function by heart rate variability. *J. Physiol Anthropol*, 38(1), 3. DOI: 10.1186/s40101-019-0193-2
- Jha, R.K., Yadav, A.K., Shrestha, S., Shrestha, P.R., Shrestha, S., Jha, M., Nepal, O. (2021). Study of Body Mass Index among Medical Students of a Medical College in Nepal: A Descriptive Cross-sectional Study. *JNMA J Nepal Med Assoc*, 59(235), 280-283. DOI: 10.31729/jnma.6282.
- Kolokoltsev, M., Romanova, E., Martirosova, T., Purtova, G., Vorozheikin, A., Guryanov, M., Balashkevich, N., Tyupa, P., Aganov, S. (2023). Physical health vector of female students from different populations and medical health groups. *Journal of Physical Education and Sport*, 23(3), 596-602. DOI:10.7752/jpes.2023.03074.
- Krasnozhan, S.V. (2017). Motor activity as a criterion of the level of health. *Physical education. Sport. Tourism. Motor recreation*, 2(1), 46-52.
- Lee, S.Y., & Gallagher, D. (2008). Assessment methods in human body composition. *Curr. Opin. Clin. Nutr. Metab. Care*, 11(5), 566-572.
- Limarenko, O. (2022). The study of students, personality properties during the period of adaptation and formation of psychophysical potential in the university. *Health, Physical Culture and Sports*, 26(2), 15-28. DOI: DOI:10.14258/zosh(2022)2.02. Retrieved from <http://hpcas.ru/article/view/11394>

- Luo, Q., Yang, L., Zhang, S., Su, J., Hao, D.M. (2018). Monitoring and evaluation of sports load for primary and middle school students. *Journal of Mechanics in Medicine and Biology*, 18(4), 1840028. DOI: 15.1142/S0219519418400286.
- Mandrikov, V.B., & Mitsulina, M.P. (2006). Methods for assessing the physical and functional state of students of a special educational department. *Educational methodical manual*. Volgograd. Volgograd State University Publishing House. Retrieved from <https://refdb.ru/look/1513972-pall.html>
- Meermanova, I.B., Koygeldinova, Sh.S., Ibraev, S.A. (2017). The health status of students studying in higher educational institutions. *International Journal of Applied and fundamental research*, 2(2), 193-197.
- Momot, O., Diachenko-Bohun, M., Hrytsai, N., Grygus, I., Stankiewicz, B., Skaliy, A., Hagner-Derengowska, M.,
- Napierała, M., Muszkieta, R. Ostrowska, M., Zukow, W. (2020). Creation of a Healthcare Environment at a Higher Educational Institution. *Journal of Physical Education and Sport*, Vol 20 (Supplement issue 2), Art 138, pp 975 – 981. DOI:10.7752/jpes.2020.s2138
- Nopin, S.V., Koryagina, Yu.V., & Kushnareva, Yu.V. (2022). Tapping test as an indicator of the effectiveness, strength and endurance of the nervous system in athletes of various sports. *Modern issues of biomedicine*, 6(2). DOI: 10.51871/2588-0500_2022_06_02_10.
- Plokhinsky, N. A. (2022). Biometrics. *Educational methodical manual*. Moscow: Moscow University Press. Retrieved from <https://search.rsl.ru/ru/record/01007326466>
- Rueggsegger, G.N., & Booth, F.W. (2018). Health benefits of exercise. *Cold Spring Harb Perspect Med*, 8(7), a029694
- Sattarov, A.E., & Karelina, N.R. (2018). Features of the growth processes in boys and boys of various body types and builds living in the southern part of Kyrgyzstan. *Pediatrician*, 9(5), 47-53
- WHO Global Database on Body Mass Index (BMI) (2012). Retrieved from <http://knoema.com/WHOGDOBMIMay/who-global-database-on-body-mass-index-bmi>
- Yu-Xiang Yan, Li-Juan Wu, Huan-Bo Xiao, Shuo Wang, Jing Dong, & Wei Wang (2018). Latent class analysis to evaluate performance of plasma cortisol, plasma catecholamines, and SHSQ-25 for early recognition of suboptimal health status. *Journal EPMA*, 9(3), 299-305. DOI: 10.1007/s13167-018-0144-8
- Zhang, Z., Chen, B., & Chen, W. (2019). The mediating effect of perceived health on the relationship between physical activity and subjective well-being in Chinese college students. *Journal of American College Health*, 1–8. DOI: 10.1080/07448481.2019.1645676
- Zurita-Ortega, F., Badicu, G., Chacon-Cuberos, R., & Castro-Sanchez, M. (2019). Motivational Climate and Physical Activity: A Multigroup Analysis in Romanian and Spanish University Students. *International Journal of Environmental Research and Public Health*, 16(11). DOI:10.3390/ijerph16112013