The gender-specific reactions of student's central nervous system to physical loads

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Abstract

Purpose: to study the response of the central nervous system and the characteristics of neurophysiological processes in students of both genders during physical load.

Material & Methods: in the study participated 58 female and 82 male students. All participants were classified as individuals with high level of physical activity according to survey data. The general health of students and their demand to participate in this study were determined by interview and examination. The reaction of the central nervous system was studied using a reflexometer according to the method proposed by T. Loskutova. The method is based on the analysis of the statistical distribution of multiple measurements of the simple visual-motor reaction time and represents a quantitative characteristic of the functional state of the central nervous system. Reflexometry was carried out at a relative resting state and at the 5th minute of recovery period after a physical load in the bicycle test, carried out according to the method proposed by D. Davidenko et al. The analysis of the obtained data was performed using Microsoft Excel 2016 and SPSS 20.0 statistical package.

Results: analysis of the obtained reflexometry data, which reflects the probabilistic and statistical principle of brain function, demonstrate insignificant fluctuations in the functional state of the brain in the majority of the examined students in a relative resting state, which were within the normal range. In accordance with the criteria for assessing the general functional state of the brain, a high and medium level of reaction stability is inherent in 76.8% male and in 84.2% female students. It should be noted that there were students who had indicators pointing to disturbances of the mechanisms of stabilization of nervous processes (3.4% female and 7.3% male students), a high degree of intensity of tonic nonspecific effects (10.3% female and 6.1% male students) and the inability to maintain an appropriate functional level (6.9% females and 9.8% males). A second assessment of the general functional state of the brain of students revealed that the average group values of indicators of the general functional state of the brain are within the age and gender norms. A certain tendency to an insignificant decrease in the stability of the reaction in both groups of subjects was noted ($p=0.918$ – in male students, $p=0.537$ – in female students), which indicates the stationary nature of the system. The stability of the functional level of the system ($p=0.821$) and the level of functional abilities ($p=0.748$) was maintained in the group of examined students. Indicators of the functional level of the system ($p=0.411$) and the functional abilities ($p=0.467$) decreased in the group of female students, indicating a deterioration in the functional state of the nervous system influenced by the dosed physical load. High and medium levels of reaction stability are characteristic of 72.4% female and 75.8% male students. It should be noted that the number of female students with pathologically low levels of reaction stability increased to 8.6%, and, conversely, the number of males with a similar level decreased to 3.7%.

Conclusions: changes in the functional state of the brain by the majority of criteria be assessed as an activation response that allows fluctuations within 25%. This reaction is characteristic of 51% of female and 63% of male students. Deviations in the range of ±25–50% are considered stress reactions and were noted in 31% and 24% of the females and males examined, respectively. Cases of overstrain with possible disruption of adaptation were recorded in 19% of female students and 12% of male students. By the majority of criteria of functional capabilities of the CNS and its reactions to dosed physical activity, the gender predominance of males was established, characterized by slightly higher stability (p=0.574), the level of CNS activation (p=0.294) and greater ability to form an adequate system of adaptation (p=0.451) to educational loads and significantly higher absolute and relative physical performance.

Key words: central nervous system, functional state of the brain, reaction stability, level of functional capabilities, functional level of the system, reflexometry, students.

Анотація

Гендерні особливості реакції центральної нервової системи студентів на фізичні навантаження. Мета: дослідити реакцію центральної нервової системи та особливості протікання нейрофізіологічних процесів у студентів обох статей під час м'язової діяльності. **Матеріали і методи:** обстежені студенти 1–2 років навчання з високою руховою активністю (58 дівчат і 82 юнака) з дотриманням всіх правил біоетики. Використовували методику оцінки функціонального стану головного мозку за даними зорово-рухової реакції. Рефлексометрія проводилась в стані відносного м'язового спокою і на п'ятій хвилині відновлення після фізичного велоергометричного навантаження, яке проводилося за методикою Д. Давиденка і співавторів. Аналіз отриманих даних проводився за допомогою статистичних пакетів Microsoft Excel 2016 та SPSS 20.0. **Результати:** за середньогруповими даними, загальний функціональний стан головного мозку обстежених дівчат і юнаків в стані відносного м'язового спокою достовірно не відрізнявся. Високий та середній рівень стійкості реакції властиві 76,8% обстеженим юнакам і 84,2% дівчатам. У деяких студентів зареєстровано порушення механізмів стабілізації нервових процесів (3,4% дівчат, 7,3% юнаків), високий ступінь напруженості тонічних неспецифічних впливів (10,3% дівчат, 6,1% юнаків) і на неможливість утримувати відповідний функціональний рівень (6,9% дівчат, 9,8% юнаків). Повторна оцінка загального функціонального стану мозку студентів встановила тенденцію до недостовірного зниження стійкості реакції в обох групах обстежених (p=0,918 – юнаки, p=0,537 – дівчата), що свідчить про стаціонарність функціонування системи. Стабільність функціонального рівня системи (p=0,821) і рівня функціональних можливостей (p=0,748) зберігалася у групі обстежених студентів. Показники функціонального рівня системи (p=0,411) і рівня функціональних можливостей (p=0,467) знизилися у групі обстежених студенток, що вказує на погіршення функціонального стану нервової системи під впливом дозованого навантаження. Високий та середній рівні стійкості реакції характерні для 72,4% дівчат і 75,8% юнаків. **Висновки:** зміни функціонального стану головного мозку обстежених оцінені як реакція активації, яка допускає флуктуації в межах 25%. Така динаміка характерна для 51% дівчат і 63% юнаків. Зрушення показників в діапазоні ±25–50% розглядаються як реакція напруження і була відмічена у 31% і 24% осіб жіночої та чоловічої статі, відповідно. Перенапруження центральної нервової системи з можливим зривом адаптації зафіксовані у 19% дівчат і 12% юнаків. Фізичні навантаження встановили гендерне превалювання у осіб чоловічої статі, що характеризувалося дещо вищими стабільністю (p=0,574), рівнем активації ЦНС (p=0,294) і кращими можливостями формувати адекватну систему адаптації (p=0,451) до навчальних навантажень, а також достовірно вищою абсолютною та відносною фізичною працездатністю.

Ключові слова: центральна нервова система, функціональний стан головного мозку, стійкість реакції, рівень функціональних можливостей, функціональний рівень системи, рефлексометрія, студенти.

Introduction

The young adulthood is characterized by various changes both in functional systems individually and in a whole organism. This age period is defined by the fine-tuning of joint functioning of all physiological systems. A balance is established as a result of strengthened neurohormonal connections in the central and peripheral components. The role of the cerebral cortex in the regulation of body functions increases significantly, the intensity of nervous processes changes, the ratio of excitation and inhibition processes in the central nervous system becomes balanced, maturation of the autonomic nervous system is being completed, and the reproductive system is being developed. All the above-mentioned processes are closely associated with changes in the interaction between the endocrine and nervous systems. As a result of ontogenetic rearrangements during young adulthood, new interconnections are being established with an increasing influence of mechanisms of the nervous regulation, as opposed to adolescence period, in which hormonal regulation prevail over mechanisms of the nervous regulation (Appenzeller, 2000; Cerritelli et al., 2021; Degtyarenko, 2011; Eunsoo Won et al., 2016; Jänig, 2008; Ivanov et al., 2014; Makarenko et al., 2011; Bosenco et al., 2017; Buchanan et al., 1992). Thus, the mechanisms of central and humoral control of life supporting processes, its individual components, in particular, working capacity of an individual, which comes to the foreground during this period are studied in the context of reforms of all levels of the educational system.

Studying is the primary activity of young adults, since the principal goal of individuals of this age period is professional orientation to their future vocation as a criterion of successful social adaptation. During this time, the nervous system becomes more activated as the center of intellectual and mental activities. The central nervous system is responsible for receiving, analyzing and transforming the information received into a targeted response, resulting in successive actions aimed at achieving the result (Antropova et al., 2006; Bosenko, 2017; Folkow, 2000; Laranjo et al., 2017; Makarenko et al., 2011; Makarchuk et al., 2011; Wolf et al., 2015). The dynamics of cortical processes, the speed of information processing, and the efficiency of integrative brain activity reflect the functional state of the central nervous system (CNS) and its adaptive capacity (Bon et al, 2022; Emanuela Zagni et al., 2016; Bodnar et al., 2012; Bosenko et al., 2017).

It should be noted that the present-day conditions for society development presuppose high expectations for intellectual and physical capacity of student youth, making the study of their physical and mental performance against the background of existing environmental problems, sedentary lifestyle, stress levels especially relevant and serve as target points in continuous control and management of health protection and strengthening process (Casey et al., 2000; Bodnar et al., 2012; Bosenko et al., 2019). At the same time, in recent years there is a trend of mixed genderless upbringing and education in schools, which, according to scientists, leads to the disappearance of young people's sexual self-identification, resulting in the deterioration of youth reproductive function due to the suppression and neutralization of male and female potentialities (Krutsevych et al., 2015; Yevstihnieieva, 2012). Therefore, gender differentiation, as a factor in preserving human health at the population level, is important in the educational and training process of children and youth (Alarcón, 2020; Mykhalyuk, 2010; Ulmer Yaniv et al., 2021; Mykhalyuk et al., 2010, 2019).

In the opinion of a number of researchers, the learning activity of an individual is determined by their productivity, which is conditioned by the depth, focus, and duration of changes in the mobility of nervous processes.

An analysis of the literature sources indicates the relevance of studying the adaptive reactions of the central nervous system of individuals differ in age and gender. This is evidenced by numerous studies conducted in the conditions of learning activities during the day, semester, and academic year. The results indicate controversial and variative degrees and orientation of changes in the functional state of the central nervous system (Shutova et al., 2013; Matsumoto et al., 2007; Topchii, 2018; Bosenko et al., 2019).

In this case, the assessment of various characteristics of the adaptation and compensatory mechanisms of the human body when the school system of education is replaced by the system of higher education plays an important role. Thus, the balance and dynamics of the principal nerve actions can be identified by registering sensorimotor reactions, showing the interaction between mental and neurophysiological mechanisms as the basis of successful intellectual activity. The study of the characteristics of sensorimotor reactions is used in neurophysiological research of various population groups. Considering such diversity, it is relevant to study the dynamics of the basic criteria characterizing the CNS function in both genders (Bosenko et al., 2019; Korobeinikova, 2011; Korobeynikov et al., 2011; Tamaki Matsumoto, 2007).

The purpose of the study the response of the central nervous system and the characteristics of neurophysiological processes in students of both genders during physical load.

Material and methods of research

Participants

The study was carried out in the Laboratory of Functional Diagnostics named after Professor Tetiana Tsonieva, Department of Biology and Healthcare, Ushynsky University. In accordance with bioethics rules 58 female and 82 male students were examined.

The persons surveyed were 1st and 2nd year students of Ushynsky University pursuing various fields of study, who were identified as individuals with high physical activity according to survey data (Krutsevich et al., 2011). The general health of students and their demand to participate in this study were determined by interview and examination.

Methods

The reaction of the central nervous system was studied using a reflexometer according to the method proposed by T. Loskutova (Topchii, 2018; Bosenko et al., 2019; Orlyk, 2019). The technique is based on the analysis of the statistical distribution of multiple measurements of the simple visual-motor reaction time and represents a quantitative characteristic of the functional state of the central nervous system. Based on the reaction time dataset, a variation curve is plotted, to determine the

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following indicators:

Tmod – the most common value of reaction time, expressed in seconds (s);

Pmax – the maximum probability corresponding to the limits of the modal class in fractions of one;

ΔT0.5 – the reaction time range at the 0.5 Pmax level, s;

T0.5 – the value of visual-motor reaction time corresponding to the mid-point of ΔT0.5 s range.

The results obtained allow calculating the functional level of the system (FLS), the reaction stability (RS), the functional capabilities level (FCL). These parameters, expressed in conventional units (c.u.) and can be calculated using the following formulas:

$$FLS = ln\frac{1}{T_{mod}} \cdot \Delta_{0.5}$$

$$RS = ln\frac{P_{max}}{\Delta T_{0.5}}$$

$$FCL = ln\frac{P_{max}}{\Delta T_{0.5}} \cdot T_{0.5}$$

FLS characterizes strain of tonic nonspecific influences. The greater the FLS, the higher the functional level of the CNS. RS reflects the degree of stability of the functional state of the nervous system. The higher the reaction stability parameter, the lower the reaction time dispersion. The FCL indicates the ability of the brain to form a high functional level and maintain it.

There is a well-known method for assessing the general functional state of the brain proposed by T. Loskutova, which requires a set of equipment consisting of 3–4 units weighing up to 20 kilograms, restricting its practical use. The psychological and physiological abilities of the researcher are naturally diminished by repeated studies requiring 30 minutes or more. Moreover, the processing and analysis of the obtained data are typically carried out manually, and this takes considerable time (1–1.5 h), does not prevent errors, and cannot produce a current and rapid assessment of the brain GFS. In view of the above, we have developed, manufactured, and tested the "Blyskavka" and the more advanced "ACHR–BOSH–1" (Bosenko, Orlyk, Shumeiko Reaction Time Analyzer–1) devices (Bosenko et al., 2006), which provide for programmable control and testing, automated logging of 60 values of the latent period of a simple reaction, followed by their transfer to a personal computer and analysis of the results. The ACHR–BOSH–1 carries out these processes automatically and displays the characteristics on a screen.

Procedure

The examination is carried out as follows: in response to light stimuli, the subject presses the button with their thumb of the "working" (dominant) arm as fast as possible. The reaction time is displayed on the device screen, recorded, and stored. The series consists of 60 signals in total, the interval between them varies in the range of 3–6 seconds to avoid the development of a reflex over time. The duration of the test is up to 6 minutes. Based on the data of the latent period (LP) of visual-motor reactions, a graph showing the distribution of their values is plotted, which characterizes the individual level of the functional state of the brain, and the study record with the calculated values of its three criteria – functional level of the system (FLS), reaction stability (RS) and functional capabilities level (FCL), the value of 60 LP is printed. The results of the survey are archived.

After receiving an instruction in the readiness state, a functional system is formed that performs a simple motor response. Its formation is associated with the need to combine various functional and specialized nerve centers into a unified system, which in turn results in a consistency of the time parameters of these centers in terms of their activity synchronization (Topchii, 2018; Vodlozerov, 2002). It should be noted that the latent period may vary significantly depending on the modality and intensity of the stimulus, as well as on complexity and automation of the stimulus, and the functional readiness of the nervous system. However, the response time to the stimulus cannot be lower than a certain physical limit, or "irreducible minimum", which equals approximately 100 ms (Topchii, 2018; Vodlozerov, 2002).

Reflexometry was carried out at relative muscular rest and at the 5th minute of recovery period after a bicycle test, carried out according to the method proposed by M. Davydenko et al. (Bosenko et al, 2009). Following this method, the load intensity was increased continuously at a constant rate (33 W/min) from zero to a certain level, determined by heart rate, whereupon the intensity was decreased to zero at the same rate. The frequency of cycling was identical for all subjects and amounted to 60 revolutions per minute. The load was reversed at the same heart rate (150–155 bpm) for all subjects. The subjects reached their individual maximum physical load capacities at the same physiological cost and performed different amounts of activity, respectively.

Statistical analysis

The study results were analyzed with Statistica for Windows 13 (StatSoft Inc., No JPZ804-I382130ARCN10-J). The data were checked for normality using the Shapiro-Wilk test. Normally distributed data reported as mean ± SD, non-normally distributed data reported as median with the interquartile range (1st quartile; 3rd quartile). Mann-Whitney test (for non-normally distributed data) and Student's paired T-test (for normally distributed data) were used to compare values between groups. The Yates's chi-square test was used to compare the frequencies of qualitative characteristics between the groups. The difference between the two subsets of data was considered statistically significant at $p<0.05$ (Fay & Gerow, 2013).

Results of the study

Prior to analyzing changes in the nervous system, the physical development and fitness of female and male students were determined. When characterizing the level of physical development of the participants, it should be noted that the females and males conformed to the norms of their level of physical activity and did not differ from their peers in the Odesa region by the main anthropometric data (Bosenko, 2017; Topchii, 2018; Orlyk, 2019). The thorax circumference of the male students at rest, during inspiratory and expiratory phases was 93 (90; 97) cm, 99 (96; 103) cm, 90 (86; 94) cm, respectively. The thorax circumference of the female students in the three conditions mentioned above measured 84 (81; 87) cm, 89 (87; 93) cm, 81 (78; 84), and were significantly lower than in male students by 9,7% ($p<0.001$), 10.1% ($p<0.001$), and 10.0% ($p<0.001$) respectively. The vital capacity of the lungs (VCL) of the male students reached 4600 (4300; 5475) ml, and the VCL of the female students was 3100 (3000; 3500) ml), which was 32.6% ($p<0.001$) lower than that of the male students. The body weight of the examined male students was 72 (68; 78) kg and body length was 178 (174; 185) cm. The body weight (56.75(53; 60) kg) and body length (164 (161.5; 167) cm) of the examined female students were lower than the similar indicators of the male students by 21.2% ($p<0.001$) and 7.9% ($p<0.001$), respectively. Results of dynamometry of the dominant arm and deadlift of the examined male subjects were 50 (42; 55) kg and 125 (105; 138, 75) kg respectively, and corresponded to the age and gender norms. This indicators in female students were within the lower limit of the age and gender norms and were lower than in male students by 48% ($p<0.001$) and 52% ($p<0.001$), respectively.

Analysis of the reflexometry data, which reflects the probabilistic and statistical principle of brain function, testifies to insignificant fluctuations in the functional state of the brain in the majority of the examined subjects at the relative rest, which were within the range of the normative values (Bosenko et al., 2019).

Based on the obtained results, the overall functional state of the brains of the female and male students examined prior to physical activity did not differ significantly (Table 1). Before data analysis a Shapiro-Wilk test was performed and did not show evidence of non-normality. In males at state of rest Shapiro-Wilk statistic for variables were: RS – W(82)=0.984, p=0.386, FLS(82) – W=0.977, p=0.144, FCL(82) – W=0.973, p=0.083), and at 5th minute of recovery period: RS – W(82)=0.990, p=0.802, FLS – W(82)=0.990, p=0.788, FCL – W(82)=0.988, p=0.623. In females at state of rest Shapiro-Wilk statistic for variables were: RS – W(52)=0.983, p=0.611, FLS – W(52)=0.979, p=0.410, FCL – W(52)=0.983, p=0.610, and at 5th minute of recovery period: RS – W(52)=0.974, p=0.248, FLS – W(52)=0.963, p=0.071, FCL – W(52)=0.968, p=0.133. Based on this outcome a parametric T-test was used.

Based on the assumption that a person demonstrates full functional abilities at an average functional level of the brain, we have identified individuals with low, medium, and high levels of CNS activation from the surveyed students in both cases (Fig. 1). In accordance with the criteria for assessing the general functional state of the brain, proposed by T. Loskutova, a high and medium level of reaction stability is characteristic of 76.8% male and 84.2% ($p=0.368$) female students examined. It should be noted that there were students who had indicators pointing to disturbances of the mechanisms of stabilization of nervous processes (3.4% of female, 7.3% of male students, $p=0.548$), a high degree of intensity of tonic nonspecific effects (10.3% of females, 6.1% of males, $p=0.548$) and the inability to maintain an appropriate functional capability level (6.9% of females, 9.8% of males, $p=0.473$).

The method of testing using a dosed physical load with reversal was chosen as a load in the form of a natural stimulus. As compared to the well-known method of assessing physical performance PWC_{170}, it is considered as more informative, time-saving and not requiring high stress of supporting and regulatory systems. Among the 8 criteria characterizing the physical performance of a subject, the

Table 1. Changes in indicators of the general functional state of the brain in female (n=58) and male students (n=82) with a high level of physical activity under the influence of bicycle physical load in a closed loop (M±SD)

Criteria	Gender	State of rest	5th minute of recovery period	p-value
RS, c.u.	M*	1.89±0.518	1.88±0.455	0.918
	F	1.89±0.528	1.83±0.602	0.537
p-value		0.991	0.574	
FLS, c.u.	M	4.7±0.311	4.69±0.305	0.821
	F	4.68±0.347	4.63±0.403	0.411
p-value		0.732	0.294	
FCL, c.u.	M	3.55±0.558	3.53±0.507	0.748
	F	3.53±0.584	3.46±0.653	0.467
p-value		0.795	0.451	

*Note: here and below M – males, F – females

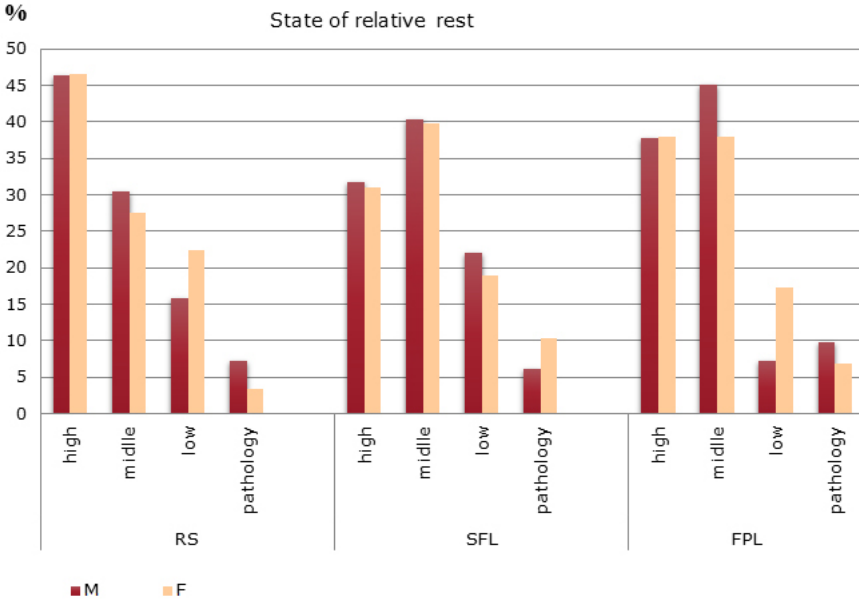

Fig. 1. CNS activation levels in female (n=58) and male (n=82) students with high physical activity at relative rest

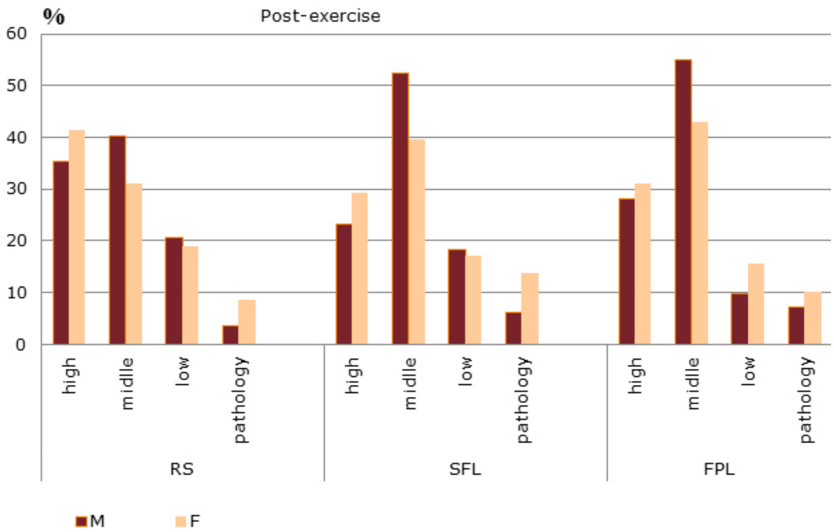

Fig. 2. Levels of CNS activation in female (n=58) and male (n=82) students after dosed physical activity in a closed loop

indicator of the total amount of physical exercise performed (A, kJ) was chosen. It was found that during the testing the total volume of the bicycle exercise performed in males was 59.4±9.82 kJ (W(82)=0.982, p=0.310), and in females was 29.7±11.11 (W(58)=0.971, p=0.191). Thus, the difference was 29.4 kJ, p<0.001.

A second assessment of the general functional state of the brain of students found that the average group values of indicators of the general functional state of the brain are within the age and gender norms.

A certain tendency to an insignificant decrease in the stability of the reaction in both groups of subjects was noted (p=0.918 in male students, p=0.537 in female students), which indicates the stationary nature of the system. The stability of the functional level of the system (p=0.821) and the level of functional abilities (p=0.748) was maintained in the group of students examined. Indicators of the functional level of the system (p=0.411) and the functional abilities (p=0.467) shown a downward trend in female students, indicating a deterioration in the functional state of the nervous system influenced by the dosed physical load (see Table 1).

The results of the assessment of the general functional state of the brain post-exercise were also analyzed for the levels of CNS activation (Fig. 2).

High and medium levels of reaction stability are characteristic of 72.4% of female and 75.8% (p=0.819) of male students. It should be noted that the number of females with pathologically low levels of reaction stability increased to 8.6%, and, conversely, the number of males with a similar level decreased to 3.7% (p=0.381). This phenomenon may indicate a higher sensitivity of the brain functioning in female students examined to the effects of physical activity and a higher strain of mobilization mechanisms in male students.

The results obtained indicate that the average data mask the individual characteristics of the functional nervous system, which makes it impossible to fully determine and assess the general functional state of the brain of the subjects.

The individual analysis revealed multidirectional dynamics of the criteria of the general functional state of the brain to physical load depending on the initial level – typically, a decrease was noted in individuals with high values of SR, FCL and FLS, and an increase was noted in students with low pre-exercise values. This allowed us to identify two key types of reaction: Type 1 – an increase – characteristic of 45% and 51%, and type 2 – a decrease – noted in 52% and 49% of the females and males examined, respectively.

Group 1, with positive post-exercise dynamics of the functional state of the brain, consisted mainly of subjects with below average and low initial brain GFS values. Conversely, Group 2, with negative post-exercise dynamics, included subjects with medium and high levels of brain GFS values (Fig. 3).

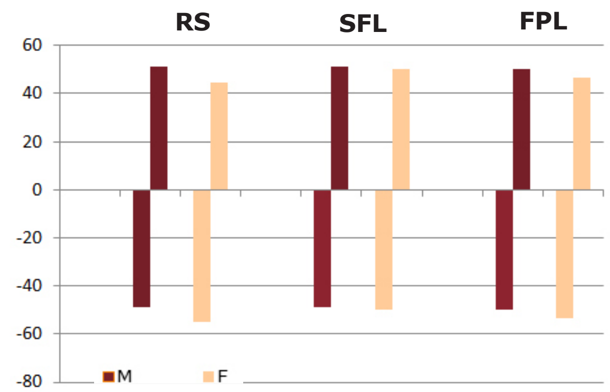

Fig. 3. Types of reaction of the CNS of male and female students to dosed physical activity in a closed loop

However, following the dependence of reaction of any structure of the body on its initial level (Wayne A. M., 1998), the "law of the pendulum", the assessment of the functional state should be carried out both in terms of the direction and depth of changes.

We revealed the lowest reactivity to the effect of dosed physical loads of the functional level of the system, which is consistent with the data published earlier (Bosenko et al., 2019; Topchii, 2018; Orlyk, 2019).

Based on the condition of the "scale of states", changes in the functional state of the brain by the majority of criteria can be assessed as an activation response that allows fluctuations within 25%. This reaction is characteristic of 51% of female and 63% of male students. Variations in the range of ±25–50% should be considered as a stress reaction of the examined students of both genders. The dynamics of the criteria with a depth of more than 50% indicates overstrain with possible disruption of adaptation, which was recorded in 19% of female students and 12% of male students.

Discussion

The problem of assessing functional states is considered as one of the most important both in general and in the physiology of physical culture and sports. Scientists study the characteristics of the body's functioning, assess the mechanisms of functional state formation, and consider psychological and physiological characteristics.

So far, it has been proven that systematic physical education and sports improve the functional capabilities of the brain. A significant characteristic of the adaptation reserve of the CNS is the ability of a person to perform muscle activity against the background of deep phase states of the brain.

However, most of these studies have been conducted involving male subjects. There is a sufficient amount of scientific data and materials involving females, however, these have a number of characteristics related to a specific biological rhythm – the menstrual cycle – and therefore may not be of a systemic nature. A lack of research on gender aspects of adaptation reactions at certain stages of ontogenesis exists.

The groups of students examined showed no differences in their average group anthropo-physiometric indices from their peers, residents of the Southern region of Ukraine. The average group data of the brain GFS also had no significant differences from the subjects of the same age and level of physical activity.

At the same time, a detailed analysis of the individual indicators of the subjects indicates diversity in the baseline levels of brain activity, both integrally and by individual criteria. This necessitates an assessment of the adaptation reactions of the CNS, taking into account group and individual characteristics of the functional state of the brain under different study conditions.

Thus, the analysis of the average group data of reflexometry carried out during the recovery period after dosed physical activity revealed no significant changes in the relationship "resting – recovery period" among male students. Under these conditions, the group of females also showed no significant changes in the level of strain of tonic nonspecific influences (p=0.451) and the level of functional abilities (p=0.467), which may indicate greater stability of the regulatory mechanisms of the CNS of the subjects. This assumption is supported by insignificant differences between the data obtained in the groups of female and male students during the recovery period according to the most integral FLS criterion (p=0.294).

Leading experts point out in their works that the dynamics of CNS criteria follow the "law of the pendulum", and therefore, the analysis of deviations should be carried out by the degree of deviation of indicators – fluctuations in the range of ±25% should be considered normal, which is regarded as activation of the system, changes in indicators within ±50% should be considered stress, and overstrain when exceeding this limit.

The prospects for further studies are to study the gender and age (children, youth, yearly and middle adulthood) characteristics of individual CNS reactions by the types "rest – increase after load" and "rest – decrease after load".

Among our subjects, 19% of female and 12% of male students showed fluctuations of more than 50%, which can be characterized as overstrain with possible disruption of adaptation. This is consistent with data of A. M. Zymkina (Bosenko et al. 2019), that disruption of cerebral homeostasis might be accompanied by fluctuations in levels of excitability, lability, and reactivity, their variations beyond physiological limits, and slow recovery or dissociation of regulatory systems.

The obtained results of our research are consistent with the data of our previous surveys of people of different age and gender groups. This supports the universality of the assessment of the brain GFS reactions, with individual dependence of its direction and depth on the initial level and strength of external factors.

Conclusions

1. An analysis of the scientific and methodological literature shows a significant number of theoretical and experimental works devoted to the study of the functional capabilities of the CNS. However, the gender features of the general functional state of the students' brain and its dynamics in response to academic loads have not yet been studied sufficiently and require further research.

2. The studies carried out by us made it possible to identify three basic levels of CNS activation at rest (low, medium, high) and to establish the stability of the functional state of the system in 76.8% of male and 84% of female students. Dosed physical activity in a closed loop with power variation causes a decrease in the stability of brain functioning in 25% and 28% of the males and females examined, respectively.

3. The high level of individuality of fluctuations in the brain GFS reduces the informativeness of the average group analysis and requires an individual approach to its assessment. The reaction of the CNS to external stimuli in the form of dosed closed loop physical activity should be assessed taking into account the "law of the pendulum".

4. Changes in the functional state of the brain by the majority of criteria be assessed as an activation response that allows fluctuations within 25%. This reaction is characteristic of 51% of female and 63% of male students. Deviations in the range of ±25–50% are considered stress reactions and were noted in 31% and 24% of the females and males examined, respectively. Cases of overstrain with possible disruption of adaptation were recorded in 19% of female students and 12% of male students.

5. By the majority of criteria of functional capabilities of the CNS and its reactions to dosed physical activity, the gender predominance of males was established, characterized by slightly higher stability ($p=0.574$), in the level of CNS activation ($p=0.294$) and greater ability to form an adequate system of adaptation ($p=0.451$) to educational loads and significantly higher absolute and relative physical performance.

Author`s contribution

Conceptualization, A.B. and Y.M.; methodology, A.B., Y.M., N.O. and MT; software, A.B., N.O. and M.T.; check, A.B. and Y.M.; formal analysis, A.B. and Y.M.; investigation, N.O. and M.T.; resources, N.O. and M.T.; data curation, N.O., M.T. and Y.H.; writing – rough preparation, A.B. and Y.M.; writing – review and editing, A.B., Y.H., N.O. and M.T.; visualization, N.O., M.T. and Y.H.; supervision, A.B.; project administration, N.O. and M.T. All authors have read and agreed with the published version of the manuscript.

Conflicts of interests

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