CONTROL OF THE REHABILITATION PROCESS OF HIGHER EDUCATION STUDENTS WITH DISABILITIES DUE TO BRAIN INJURIES BY COMPUTER ENGINEERING TOOLS

КОНТРОЛЬ РЕАБІЛІТАЦІЙНОГО ПРОЦЕСУ ЗДОБУВАЧІВ ВИЩОЇ ОСВІТИ З ІНВАЛІДНІСТЮ ВНАСЛІДОК ЧЕРЕПНО-МОЗКОВИХ ТРАВМ ІНСТРУМЕНТАМИ КОМП'ЮТЕРНОЇ ІНЖЕНЕРІЇ

Ladyniak A. B.[1], Chubinska N. B.[2], Chervinska O. S.[3]
[1]*Kamianets-Podilskyi Ivan Ohiienko National University, Kamianets-Podilskyi, Ukraine*
[2, 3]*Lviv Polytechnic National University, Lviv, Ukraine*
[1]*ORCID: 0000-0001-6096-5902*
[2]*ORCID: 0000-0002-4803-2453*
[3]*ORCID: 0000-0002-6048-7936*

DOI https://doi.org/10.32782/2522-1795.2024.18.2

Abstracts

The issue of rehabilitation of students with disabilities as a result of the war in higher education is currently one of the most urgent since their number is constantly increasing due to the continuation of military operations and terrorist attacks in Russia. **The purpose of the research** was to determine the reliability and validity of the developed information system for controlling balance, posture, range of motion, and proprioceptive abilities of disabled students with brain injuries as a result of war. **Material.** 42 first-year students with disabilities who received mild head brain injuries as a result of the war were involved in the study. **The results.** An information system has been developed for the implementation of the test process and automated data collection. The information system is built on the basis of the latest achievements in computer engineering and developed software. The basis of our development is a network of distance sensors, which have different sensitivities depending on the required functions, but their main characteristic is the range, or detection zone. The information on the student's performance of the test task is recorded by a network of sensors and automatically transmitted to the controller by Bluetooth wireless means of information transmission, and then to a personal computer with a simple graphic interface. The obtained values are processed by the developed software, filtered and presented graphically and in numerical units. According to the results of the correlation analysis, it was established that the numerical values of test reliability and validity, in the case of fixation of the results by the developed information system, reach the "high" value. On the other hand, in the case of fixing the results traditionally, the reliability is at the level of "medium", and the validity is "low". **Conclusions.** The application of technological achievements of computer engineering in the process of physical rehabilitation is the basis of improvement and objectification of methods of data collection, their analysis and interpretation, and, therefore, a leading factor in obtaining competitive advantages in the process of permanent control of the rehabilitation process. The use of the developed information system contributes to the objectivity of control and significant time savings, as it ensures immediate results and the elimination of mechanical and mathematical errors in the processing of results and their presentation.

Key words: rehabilitation, control students with disabilities, brain injuries, information system.

Питання реабілітації здобувачів вищої освіти з інвалідністю внаслідок війни у вищій освіті нині є одним із найактуальніших, оскільки їхня кількість внаслідок продовження військових дій та терористичних атак росії постійно зростає. Мета роботи полягала у визначенні надійності та валідності розробленої інформаційної системи для контролю рівноваги, постави, діапазону рухів та пропріоцептивних здібностей здобувачів вищої освіти з інвалідністю з черепно-мозковими травмами внаслідок війни. Матеріал та методи. Дослідження реалізовано з використанням методів теоретичного (аналіз, синтез, узагальнення) та емпіричного (експеримент, моделювання, тестування, математичної статистики) рівнів. До дослідження були залучені 42 здобувачі вищої

освіти І курсу навчання з інвалідністю, які отримали черепно-мозкові травми легкого ступеня внаслідок війни. Результати. Розроблено інформаційну систему для реалізації тестового процесу та автоматизованого збору даних. Інформаційна система сконструйована на основі новітніх здобутків комп'ютерної інженерії та розробленого програмного забезпечення. В основі нашої розробки – мережа датчиків відстані, які мають різну чутливість залежно від необхідних функцій, але основна їхня характеристика – це діапазон, або зона виявлення. Інформація виконання тестового завдання здобувачем вищої освіти фіксується мережею датчиків та автоматично безпровідними засобами передачі інформації Bluetooth передається на контролер, а далі на персональний комп'ютер. Отримані значення обробляються розробленим програмним забезпеченням, фільтруються та представляються графічно та у числових одиницях. За результатами кореляційного аналізу встановлено, що числові значення тестової надійності та валідності у разі фіксації результатів розробленою інформаційною системою досягають значення «висока». Натомість, у разі фіксації результатів традиційним способом надійність на рівні «середньої», валідність – «низька». Висновки. Застосування технологічних досягнень комп'ютерної інженерії у процесі фізичної реабілітації здобувачів вищої освіти в процесі навчання є основою покращення та об'єктивізації методів збору даних, їхнього аналізу та інтерпретації, а тому провідним фактором отримання конкурентних переваг у процесі перманентного контролю реабілітаційного процесу. Використання у практиці інклюзивного фізичного виховання розробленої інформаційної системи сприяє об'єктивності контролю та суттєвій економії часу, оскільки забезпечує негайне отримання результату та виключення механічних і математичних помилок у обробці результатів та їхньому представленні.

Ключові слова: реабілітація, контроль, здобувачі вищої освіти з інвалідністю, черепно-мозкова травма, інформаційна система.

Introduction. The long-term large-scale aggression of the russian federation against Ukraine reaches a two-year term. War has a comprehensive effect on the physical health of not only military personnel but also the civilian population. As a result of prolonged hostilities and daily shelling of the civilian population, the number of injured persons is increasing daily.

Shell shock, wartime neurosis, Vietnam syndrome – phenomena of the consequences of military trauma [18]. Brain concussion occupies a leading place in the structure of military injuries. Such a traumatic injury is considered a mild brain injury (BI). The BI is mostly the result of a blast wave, which has a significant, but often invisible impact on the brain with quite significant consequences [29].

A large number of soldiers after demobilization as a result of BI and civilians who acquired the status of persons with disabilities as a result of the war replenished the ranks of higher education recipients. Providing conditions for obtaining the appropriate level of education for such persons is a powerful challenge for the educational system of Ukraine [1]. Our state, as a participating state of the Convention on the Rights of Persons with Disabilities [7], recognizes the right of persons with disabilities to education, providing inclusive education based on equal opportunities. Therefore, persons with disabilities as a result of the war become full participants in the educational process.

Obtaining new scientific data on the rehabilitation of students with disabilities as a result of the war is a social need of Ukrainian society against the background of the development of educational institutes and the integration of Ukraine into the European educational community.

In the conditions of education in institutions of higher education, the function of rehabilitation, aimed at meeting the needs of students with disabilities in dosed physical activity and maintaining health by eliminating the consequences of BI, is performed by inclusive physical education. Therefore, in the context of the complex rehabilitation of such persons in the environment of the constant destructive influence of the war, and the injuries received as a result, it is relevant to study the possibilities of inclusive physical education in this process.

Analysis of recent research and publications. The topic of rehabilitation of students with disabilities as a result of the war in higher education is currently one of the most relevant, as their number is increasing in the conditions of the long-term continuation of military operations and terrorist attacks in the russian federation.

Inclusive physical education is a modern innovative trend [2; 15], which is widely discussed in scientific circles. Scientists from various fields continue to study various aspects of this issue and create new methods of physical education based on them for the effective inclusion of people with disabilities [3; 31]. scientists of various fields continue to research various aspects of this issue and create, based on them, the development of the latest methods of work, education and training for the effective inclusion of people with disabilities

In the field of modern scientific interests, the issue of rehabilitation of students with disabilities in the process of physical education in connection with military operations has acquired special significance [1]. It has been emphasized [19, 30] that timely comprehensive rehabilitation with BI will allow for compensating the damage as efficiently as possible.

At the same time, it was investigated [21; 31] that the implementation of rehabilitation measures in the process of physical education depends on the individual capabilities and needs of students. It has been proven [15] that this requires constant monitoring of indicators that correlate with the elimination of deviations in the health status of students with disabilities.

Qualitative searches for the main trends in the development of inclusive physical education in the international educational space are significant not only in a purely theoretical dimension but also in the practical sphere [31]. Certain scientific developments related to the modernization of inclusive physical education are aimed at combining classes in useful proportions and methods of monitoring their effectiveness. Scientific developments related to the modernization of inclusive PE are aimed at combining classes in useful proportions and methods of monitoring their effectiveness [2; 16].

It was determined [3] that the application of technical means of monitoring and control of this process plays a very important role in ensuring the success of rehabilitation. From this point of view, the introduction of new modern technologies in the control of physical education is considered [1; 21] as an opportunity to ensure the effectiveness and objectivity of this process. It is believed [35] that such an approach fully corresponds to the current progress of the industry. It is proven [35] that meeting the challenges of today in terms of the paradigm of educational changes requires the introduction of new technologies in the PE process, corresponding to modern challenges.

Therefore, taking into account the fact that the relevance of the BI problem in the conditions of war is extremely high, as a result of prolonged hostilities on the territory of Ukraine, and the importance of providing competent rehabilitation measures for students with disabilities in the process of inclusive physical education based on the latest achievements of technical development, the purpose of further research.

The purpose of the research was to determine the reliability and validity of the developed information system for controlling balance, posture, range of motion, and proprioceptive abilities of disabled students with brain injuries as a result of war.

Materials and methods. *Research methods.* Our search intelligence was built based on a search strategy and assessment of the quality of the subject under investigation. By nature, our research is classified as primarily applied research.

Practical implementation, according to the logic of scientific research, requires conducting research at the theoretical and empirical level for a deeper understanding of the problem. Therefore, the relevance and significance of the research were determined and the structural basis for the systematic organization and interpretation of data was outlined.

The theoretical level involved the use of methods of analysis and synthesis, induction and deduction, generalization for logical research of collected facts and formation of conclusions. At this level, we tried to investigate the subject, which became the basis for the formation of the theoretical structured basis of our scientific search.

Taking into account that our research is implemented at the intersection of fields of knowledge, combining ideas from various

theories, we tried to create an interdisciplinary basis for the development of innovative solutions to the problems of scientific intelligence. Thus, forming a theoretical basis, we provided a basis for data interpretation.

The empirical level involved the use of the technical modelling method to create an information control system, to obtain the necessary experimental information, a pedagogical experiment, testing and mathematical processing of the obtained data using specific scientific methods. The methods of mathematical statistics are used as specific scientific methods.

The "Star Excursion Balance Test" (SEBT) was used in pedagogical testing. The SEBT [34] is dynamic, a quantitative assessment tool used to monitor a person's posture, range of motion, strength, and proprioceptive abilities.

In our study, taking into account the contingent of students with disabilities, it was considered appropriate to apply the SEBT, which is recommended for use in traumatized individuals [8], as a reliable clinical tool for operational assessment [12].

Test procedure. The test methodology assumes that the student must maintain balance on one leg while performing the test task. Tasks are performed barefoot. The test procedure [8; 10] assumes that the student's foot takes a position in the center. The other foot remained free, which must be stretched as far as possible alternately in different directions of the eight axes that form the contour of the star.

The attempt is considered invalid if the student loses balance, as a result of which the foot in the center violated a stable position and in the case when the other foot did not touch the axis.

Study participants. 42 students in the 1st year of studies with disabilities, who received BI of a mild degree as a result of the war, were involved in the study Kamianets-Podilskyi National Ivan Ohiienko University and Lviv Polytechnic National University. The sample size was formed based on the method of calculating the required number of subjects in reliability research, where reliability is measured using intraclass correlation [33]. Therefore, the size of the study sample met the requirements of conducting a correlational study.

Since we were guided by the conclusions [34], regarding the lack of difference in test reliability by gender, the sample was formed randomly. Before the test, basic information was collected regarding compliance with the criteria for inclusion in the research sample. The criteria were as follows: the presence of BI of a mild degree, obtained as a result of war, the absence of concomitant injuries, the absence of cardiovascular, mental and neurological diseases, a history of balance disorders, and the absence of pain during the test.

All participants of the studied sample signed informed consent forms before testing regarding the voluntariness and anonymity of participation in the study. Permission to participate in the experiment of each participant of the studied sample was obtained from the doctor. In this way, they tried to achieve the possibility of bias in the collection and analysis of test results, while ensuring confidentiality.

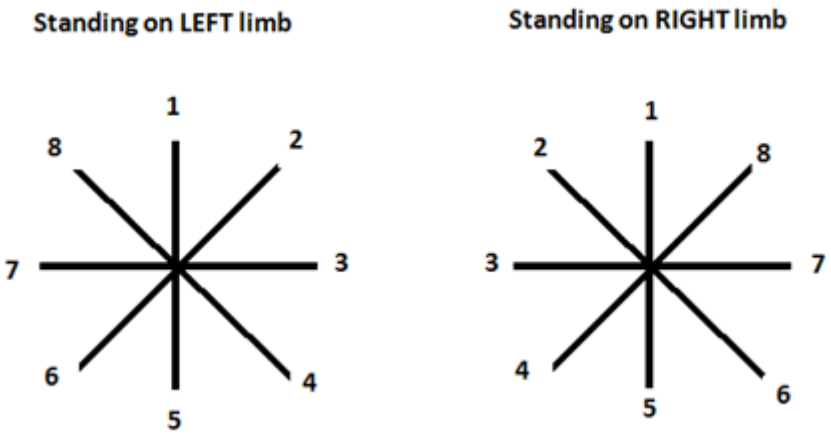

Fig. 1. Scheme of the test [8]

The study was planned and carried out following the principles of bioethics set forth by the World Medical Association (WMA-2013) in the Helsinki Declaration "Ethical Principles of Medical Research Involving Humans" and UNESCO in the "General Declaration on Bioethics and Human Rights".

Research organization. An experiment based on the proposed algorithm for changing the experimental factor. The experimental factor provided for the quantitative evaluation of test control results in two ways. In the first case, a measuring tape attached to the floor was used. In the second, the results were recorded using the developed information control system. In this way, they ensured the implementation of the triangulation strategy (Triangulation) [32]. According to this strategy, two sources of data collected by different methods about the same phenomenon in a controlled research environment were used. Therefore, try to avoid any research bias in your work.

The experiment provided for each student to perform the test exercise three times. Research was conducted during the academic semester, testing was carried out at the end of the month within the educational discipline of inclusive physical education. They tried to conduct repeated studies in the most stereotypical conditions. The order of limb selection by the student for performing the test task was randomized.

The average value of the obtained results was used for data analysis. In evaluating the results and generating evidence, we were guided by the data that the results obtained with the use of the measuring tape and the developed information system cannot be considered identical.

*Statistical analysis.*In order to interpret the results of research, extract valuable information from the data obtained by experiment, make informed decisions, and check the proposed assumptions, the methods of mathematical statistics are applied. Statistical correlation analysis, the main advantage of which is simplicity in the identification of the necessary variables, determines the degree of reliability and validity of the studied tests [32]. The correlation coefficient becomes the main tool for measuring the validity and reliability of the information system developed in the research process. In forming conclusions about test reliability, be guided by the fact that a correlation coefficient of 0.7 and above is considered satisfactory.

The interpretation of the obtained values of the correlation coefficient became the basis of the conclusions regarding the studied indicators. All statistical analyses were performed using SPSS Version 22.0 (IBM Corporation).

Results. First of all, our research required understanding that mild BI is actually a concussion. This condition occurs as a result of a blow, a fall, and under the action of an explosive wave that "hits" the blood vessels, skull, and brain [18, 30].

It is taken into account that BI has quite serious consequences, which leads to a violation of the normal function of the brain. Physiological symptoms include imbalance, disorientation in space, and deviations in proprioception [19]. This is a factor in the occurrence of deviations in the trajectory characteristics of the general center of mass, suppression of pathological muscle synergies and hyperkinesis, caused by a decrease in muscle tone, the development of establishing and postural reflexes, etc. [29].

Our further research was guided by the fact that the level of maintaining balance and proprioceptive abilities, which are a prerequisite for any regulated motor function [2], is often an important criterion used in the control of the rehabilitation process after BI [25]. In addition, rehabilitation of persons after BI is aimed at restoring fine motor skills, and maintaining correct posture and physiological forms when walking [19].

The collected information became the basis of our scientific search. Given that the collection of relevant primary data is critical to achieving the research objective, an information system was developed to implement the SEBT test process and automated data collection. The information system is built on the basis of the latest achievements in computer engineering and developed software.

The basis of our development is a network of distance sensors, which have different sensitivity

depending on the required functions, but their main characteristic is the range, or detection zone [22]. The developed device includes ultrasonic or infrared distance sensors that record the movement of objects in space and launch certain tasks depending on the received indicators. The feasibility of the synthesis in our development of two types of sensors is due to the higher level of accuracy of infrared sensors.

Sensors were placed in eight different directions of the test and the center of the supporting leg. To build the device, we used HC-SR04 ultrasonic sensors (Figure 2a) and VL53L0X infrared sensors (Figure 2b).

The principle of operation of the used ultrasonic sensors is based on the change of sound waves and works according to the principle of ultrasonic echolocation. With a certain periodicity, such a sensor emits ultrasonic waves into the surrounding space and captures information about movement. The principle of operation of infrared sensors is based on the detection and analysis of changes in the movement of the light flux when performing movements [22].

Such sensors have different sensitivities depending on the required functions, but the main characteristic can be the detection range or zone. The detection zone is the area of space in which the motion sensor is guaranteed to detect an object. Among the main characteristics of these sensors is the distance measurement range: 2–400 cm with an accuracy of up to 3 mm. The lack of interfaces is offset by the simplicity of the sensor.

Infrared sensors contain a transmitter and a receiver in the infrared range. Distance measurement range: from 1 cm to 200 cm, which is automatically adjusted. A graphical interface is used in the device to switch active sensors and, accordingly, select the direction.

In the developed information system, an array of eight sensors with alternate activation is used to avoid overlap of measurement zones. An array of sensors is alternately connected to the controller, and then to a PC with a simple graphical interface.

To fix the test results, we take the total distance from the center where the supporting leg moves to the sensor as 1. Accordingly, to determine the distance of the leg, the value measured by the sensor must be subtracted from the total value. The software has been developed to implement these operations.

With the use of software developed for the implementation of the test process, results are filtered, sequenced, graphically displayed, stored in internal memory, archived and made available at any time.

The work of the information system is carried out as follows: the student, while performing the test task, alternately, according to the test task, touches the determined lines with his foot. The information on the student's performance of the test task is recorded by the network of sensors and automatically transmitted to the controller, and then to the personal computer. All communication lines in our device are implemented by Bluetooth wireless means of information transmission.

The information system makes it possible to clearly record the task execution time and automatically limit the test task execution time. Among the main advantages of using the developed information system in practical work:

Fig. 2. Sensors used to build the information system network: a) ultrasonic HC-SR04, b) infrared VL53L0X

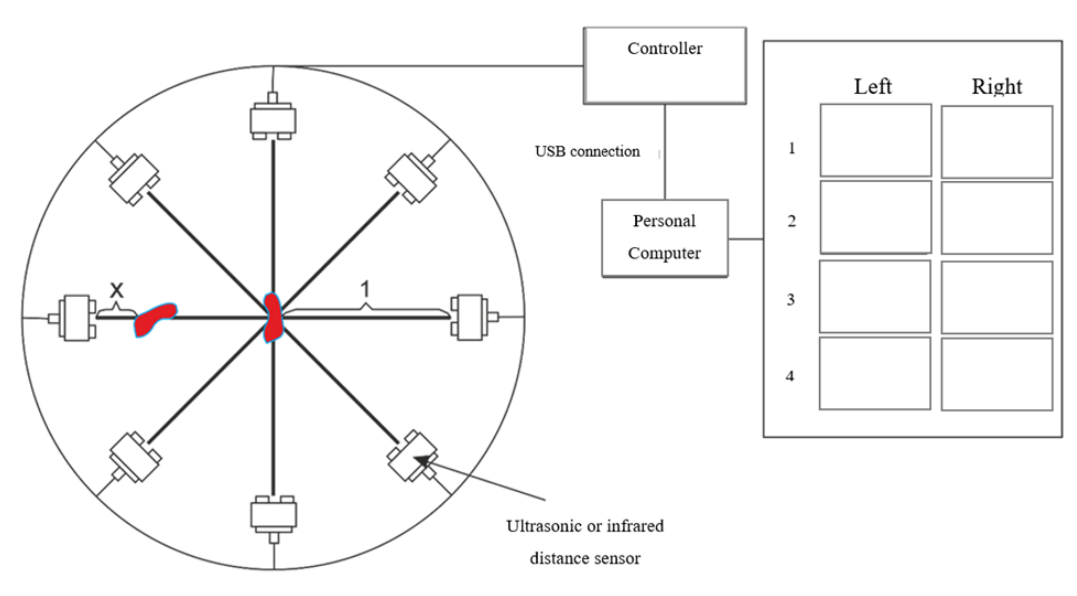

Fig. 3. Schematic representation of the information system for implementation SEBT-test

are immediate obtaining of results, objectivity of control, availability of results, their presentation in digital and graphic form, and the possibility of their storage in the database.

A pragmatic way of evaluating the effectiveness of the information system required the data collected for our study, which became the basis of their analysis. The process of testing and collecting results was carefully controlled, therefore, the obtained data became the basis for the conclusion about the differences of tools in data collection. Carefully collected data were systematically analyzed by the defined research objective. The results are presented in table 1.

Therefore, according to the numerical values of reliability, which were obtained by the traditional way of fixing the results by the teacher, they correspond to the value "suitable for use with a certain group of people". However, this cannot be achieved with students with disabilities due to the variability of individual physiological reactions to the received BI. Also, to a certain extent, these results are due to the physical condition of the students of the studied sample, which is practically impossible to achieve homogeneity.

Accordingly, the numerical values of the test reliability, in the case of fixation of the results by the developed information system, reach the value "high".

Regarding the obtained results, according to which we observe a decrease in the degree of reliability in three attempts. Meaningful aspects of the research take place. In particular, during the break due to the implementation of rehabilitation measures and external conditions, there are certain changes in the state of the investigated indicators. This naturally affected the decrease in the retest reliability indicator. In addition, the influence of the emotional state and well-being (in particular, the state of fatigue) of the students of the studied sample is not excluded.

Table 1

The reliability and validity of the SEBT-test (n – 42)

Parameters	Correlation coefficient (rtt)					
	TW	IS	TW	IS	TW	IS
reliability	0.717	0.891	0.734	0.912	0.751	0.924
validity	0.282	0.693	0.277	0.765	0.291	0.741

**Note: TW – traditional way; IS – information system*

Therefore, a slight decrease in the degree of reliability over long periods of time did not affect the validity indicators. The obtained values of the validity of the test, the results of which were recorded by the developed information system at the «high» level, allow faster, cheaper and better implementation of test control.

On the contrary, the results of the correlation analysis proved that in the case of fixing the results traditionally, the indicators of validity correspond to the value "low".

Discussion. Our research is based on the fact that at the current stage of the development of education in Ukraine, which is determined by the new realities of the challenges of the long-term military aggression of the russian federation against Ukraine, there is an urgent need to introduce new forms, methods, and means of inclusive physical education as the main means of rehabilitation of students with disabilities in institutions of higher education We agree with the opinion [1; 3; 23] that Ukrainian higher education has an urgent need to form a system of rehabilitation measures adequate to its modern development.

The relevance of the declared scientific research is because today mild BI is one of the most acute problems of the health care system of Ukraine. This situation is caused by the fact that as a result of a long-term full-scale war on the territory of our country, the risk of obtaining a BI applies without exception to all citizens of our state. According to official statistics [17], in Ukraine before the start of the full-scale invasion, the number of BI was 120.000 cases/ year, and due to active military operations, such indicators doubled. Moreover, both servicemen and civilians are equally at risk of receiving BI as a result of the blast wave [19]. Therefore, the number of students with disabilities due to BI in institutions of higher education is constantly increasing.

We agree with our research [18; 29] that BI is a complex multidisciplinary medical and social problem, as well as one of the leading causes of morbidity, including endocrine and cardiovascular diseases, a factor of disability and mortality. The consequences of BI tend to manifest themselves for a long time, therefore, post-traumatic conditions require constant monitoring of the rehabilitation process [30].

We consider monitoring the rehabilitation process of students with disabilities due to BI as a means of increasing the efficiency, objectivity and impartiality of this process. Our study expands the range of scientific knowledge [17] regarding the implementation of computer engineering developments in this process. We agree with the opinion [2; 3; 35] that this is how an innovative vector of development of the field of inclusive physical education, corresponding to modern demands, is realized.

For the first time, the work presents the developed information system, which is recommended to be used in the control of the rehabilitation process of persons with disabilities due to BI. Because the main consequences of BI are a violation of balance, translational control, and orientation in space, we considered it necessary to take the star excursion balance test as a basis [25]. Until now, this control technique has been evaluated in healthy populations [10; 20; 28] and athletes [9; 24; 27; 36]. A simplified version of the SEBT-test is often used [12] to detect functional deficits in various diseases of the musculoskeletal system [6; 8; 26], and research of lower limb muscle strength in young healthy women [5].

For the first time, we evaluated the reliability of the test when using it as a means of control for persons with disabilities due to BI. This is consistent with findings [11; 28] regarding the need for further evaluations to determine the reliability and utility of the SEBT-test in a wide range of populations.

At the same time, we support scientific approaches regarding the extreme importance of having tools to monitor and determine improvements in the rehabilitation process [14; 25].

The data of our previous studies [1–3; 21] confirmed that the use of computer engineering developments, and devices created by the synthesis of IT data collection tools and software contribute to a significant increase in the efficiency and effectiveness of monitoring the results of the rehabilitation process of inclusive physical education.

The practical significance of the research results lies in the possibility of using the obtained control results using the developed information system to create individually oriented methods of physical rehabilitation for students with disabilities due to BI in order to level the features and limitations that complicate adaptation and the learning process in a higher education institution based on impartiality in inclusion of students affected by the war.

Conclusions. The long-term full-scale invasion of the russian federation on the territory of Ukraine became a factor of fundamental changes in the educational environment of higher schools, in particular inclusive physical education, aimed at solving applied scientific and practical problems related to the rehabilitation of students with disabilities during education. At the same time, the studied contingent is not only military personnel who took direct part in hostilities but also students who suffered from the war. It was determined that currently the most widespread among students with disabilities is the percentage of BI. In the conditions of prolonged hostilities, the rehabilitation of students' health is one of the most urgent problems of our time.

We consider the benchmarks for solving this problem from the standpoint of physical rehabilitation, based on the use of forms, means, and methods of inclusive physical education in combination with computer engineering developments. In terms of monitoring the indicators that correlate the rehabilitation process of students with disabilities due to BI and the teacher receiving urgent information about the current and (or) achieved state of balance, posture, range of motion, and proprioceptive abilities, an information system was developed based on the latest achievements in computer engineering and programming. To avoid bias in the control results, and the possibility of obtaining an immediate result, a measure of reliability and validity of the developed information system was established, which, according to the obtained numerical indicators, corresponds to the «high» level. That enables the justified use of control results for conclusions and analysis of the rehabilitation process.

Since the field of computer engineering is in a state of permanent development, the application of technological achievements is the basis for improving and objectifying methods of data collection, their analysis and interpretation, and, therefore, is a leading factor in obtaining competitive advantages in the field of rehabilitation. In the process of test control, the use of the developed information system contributes to significant time savings, as it ensures immediate results. In addition, the possibility of mechanical and mathematical errors in the processing of control results and their presentation is excluded.

The use of the developed information system in practical activities enables a thorough study of the basics of physical rehabilitation of students with disabilities due to BI and the creation of innovative pedagogical and physical rehabilitation practices for their introduction into inclusive physical education as the basis of the effectiveness of this process.

References

1. Blavt, O., Bodnar, A., Mykhalskyi, A., Gurtova, T., Tsovkh, L. (2023). Application of Electronic Means in Endurance Coordination Testing of Students with Disabilities Who are War Veterans. *Physical Education Theory and Methodology,* 23(3), 397–403. https://doi.org/10.17309/tmfv.2023.3.12.

2. Blavt, O., Chaplinskyi, R., Prozar, M., Pityn, M., Helzhynska, T., Dmytruk, V., Hrebik, O., Kovalchuk, V. (2023). The Efficiency of the Application of Electronic Techniques in the Control of Dynamic Balance in the Process of Inclusive Physical Education. *Physical Education Theory and Methodology*, 23(5), 770–776. https://doi.org/10.17309/tmfv.2023.5.16.

3. Blavt, O., Iedynak, G., Pereverzieva, S., Holub, V., Melnyk, S. (2023). Increasing the Reliability of Test Control Using Information Technologies in Inclusive Physical Education. *Physical Education Theory and Methodology*, 23(4), 607–613. https://doi.org/10.17309/tmfv.2023.4.16.

4. Blavt, O., Iedynak, G., Pityn, M., Hluhov, I., Guska, M., Stadnyk, V., Zaikin, A., Karatnyk, I. (2022). Implementation of Information and Communication Technologies in Test Control of Leg Strength in Physical Education of Students. *Physical Education Theory and Methodology*, 22(3s), 110–116. https://doi.org/10.17309/tmfv.2022.3s.15.

5. Bulow, A., Anderson, J.E., Leiter, J.R., MacDonald, P.B., Peeler, J. (2019). The modified star excursion balance and y-balance test results differ when assessing physically active healthy adolescent females. *Int J Sports Phys Ther*., 14(2), 192–203. https://doi.org/10.26603/ijspt20190192.

6. Chaiwanichsiri, D., Lorprayoon, E., Noomanoch, L. (2005). Star excursion balance training: effects on ankle functional stability after ankle sprain. *J Med Assoc Thai*, 88(4), 90–4.

7. Convention on the rights of persons with disabilities. Retrieved from: https://zakon.rada.gov.ua/laws/show/995_g71#Text) № 8006/0/2-23/61 (Last accessed: 19.10.2023).

8. Gribble, P.A., Herte,l J., Plisky, P. (2012). Using the Star Excursion Balance Test to assess dynamic postural-control deficits and outcomes in lower extremity injury: a literature and systematic review. *J Athl Train.*, 47(3), 339–57. https://doi.org/10.4085/1062-6050-47.3.08.

9. Haqiyah, A., Sanjaya, K.H., Riyadi, D.N., Lestari, W.D., Kusmasari, W., Lubis, J.Y., Hanief, Y.N. (2023). Validity of the modified star excursion balance test (mSEBT) in martial art athletes. *Journal of Physical Education and Sport*, 23(4)103, 817–823. https://doi.org/10.7752/jpes.2023.04103.

10. Hertel, J., Braham, R., Hale, S., Olmsted, L. (2006). Simplifying the Star Excursion Balance Test: Analyses of subjects with and without ansk nestability. *J Orthop Sports Phys Ther.*, 36, 131–137.

11. Hertel, J., Miller, S.J., Denegar, C.R. (2000). Intratester and intertester reliability during the star excursion balance tests. J Sport Rehabil., 9(2), 104–116. https://doi.org/10.1123/jsr.9.2.104.

12. Horsak, B., Simonlehner, M., Dumphart, B., Kainz, H., Killen, B., Jonkers, I. (2022). Patella-femoral joint loading during the modified Star Excursion Balance Test: Preliminary results of an extensive simulation study. *Gait & Posture*, 97. 5–6. https://doi.org/10.1016/j.gaitpost.2022.07.013.

13. Hyong, I.H., Kim, J.H. (2014). Examining intra-rater and intra-rater reliability for the Star Excursion Balance Test. *J. Phys. Tel. Sci.*, 26, 1139–1141.

14. Kaminski, T.W., Gribble, P. (2003). The star excursion balance test as a measurement tool. *Athl Ther Today*, 8(2), 46–47.

15. Kuntjoro, B.F.T., Soegiyanto, S., Setijono, H., Suhiharto, S. (2022). Inclusion of students with disability in physical education: analysis of trends and best practices. *AJPESH,* 2(2), 88–94.

16. Matiychuk, V.I., Vlasyuk, G.I. (2023). Postural control in physical education of youth students. *Rehabilitation and Recreation*, 15, 249–253. https://doi.org/10.32782/2522-1795.2023.15.32 [in Ukrainian].

17. Medical newspaper "Health of Ukraine of the 21st Century" (2023). 5–6 (541–542). Retrieved from: https://health-ua.com/multimedia/userfiles/files/2023/ZU_5-6_2023/ZU_5-6_2023_32-33.pdf L.A. [in Ukrainian].

18. Merritt, V.C., Lange, R.T., French, L.M. (2015). Resilience and symptom reporting following mild traumatic brain injury in military service members. *Brain Injury*, 29(11), 1325–1336. https://doi.org/10.3109/02699052.2015.1043948.

19. Misyura, V.B., Ruban, L.A., Mishin, M.V. (2022). Vestibular rehabilitation of amateur athletes after brain injuries. *Rehabilitation and Recreation*, 12, 198–203. https://doi.org/10.32782/2522-1795.2022.12.26 [in Ukrainian].

20. Mohammad, W.S., Alotaibi, S., Al Sayeid, S., Al Khalif, N., Al Shaibani, A., Elsais, W. (2023). Exploring the Relationship between Muscular Strength, Flexibility, and mSEBT Test Performance in Saudi Arabian Women. Appl. Sci., 13*,* 12355. https://doi.org/10.3390/app132212355.

21. Mykytyuk, Z., Blavt, O., Hnatchuk, Ya., Stechkevych, O., Helzhynska, T. (2022). Intensification of Back Muscle Strength Testing in Physical Education of Students by Applying Information and Communication Technologies. *Teorìâ ta Metodika Fìzičnogo Vihovannâ,* 22(2), 216–222. https://doi.org/10.17309/tmfv.2022.2.10.

22. Mykytyuk, Z., Kremer, I., Ivakh, M., Diskovskyi, I., Khomyak, S. (2021). Optical sensor with liquid crystal sensitive element for monitoring acetone vapor during exhalation. *Molecular Crystals and Liquid Crystals,* 721, 1–6. https://doi.org/:10.1080/15421406.2021.1905273.

23. Novopysmennyi, S., Diachenko-Bohun, M., Hrytsai, N., Grygus, I., Muszkieta, R., Napierala, M., Hagner-Derengow-

ska, M., Ostrowska, M., Smolenska, O., Skaliy, A., Zukow, W., Stankiewicz, B. (2020). Implementation of electronic health control technologies in higher education institutions. *Journal of Physical Education and Sport,* 20 (Supplement issue 2), 921–928.

24. Picot, B., Dury, J., Néron, G., McKeon, P.O., Forestier, N. (2022). Establishing Normative Dynamic Postural Control Values in Elite Female Handball Players. *Int J Sports Phys Ther*, 1, 17(6), 1083–1094. https://doi.org/10.26603/001c.38174.

25. Picot, B., Terrier, R., Forestier, N., Fourchet, F., McKeon, P. (2021). The Star Excursion Balance Test: An Update Review and Practical Guidelines. *International Journal of Athletic Therapy & Training*, 26, 285–293. https://doi.org/26.10.1123/ijatt.2020-0106.

26. Pionnier, R., Découfour, N., Barbier, F., Popineau, C., Simoneau-Buessinger, E. (2016). A new approach of the Star Excursion Balance Test to assess dynamic postural control in people complaining from chronic ankle instability. *Gait Posture,* 45, 97–102. https://doi.org/10.1016/j.gaitpost.2016.01.013.

27. Plisky, P.J., Rauh, M.J., Kaminski, T.W., Underwood, F.B. (2006). Star Excursion Balance Test as a predictor of lower extremity injury in high school basketball players. *Journal of Orthopaedic & Sports Physical Therapy*, 36(12), 911–9.

28. Powden, C.J., Dodds, T.K., Gabriel, E.H. (2019). The reliability of the star excursion balance test and lower quarter y-balance test in healthy adults: a systematic review. *Int J Sports Phys Ther.*, 14(5), 683–694.

29. Reid, M.W., Cooper, D.B., Lu, L.H. et al. (2018). Adversity and Resilience Are Associated with Outcome after Mild Traumatic Brain Injury in Military Service Members. *Journal of Neurotrauma*, 10, 1146–1155. https://doi.org/10.1080/08995605.2021.1962191.

30. Schnittker, J. (2018). Scars: The long-term effects of combat exposure on health. *Socius: Sociological Research for a Dynamic World*, 4, 2378023118813017. https://doi.org/10.1177/2378023118813017.

31. Shchekotilina, N.F. (2023). *Inclusion in physical culture: a study guide*. Odesa: Ushinsky University [in Ukrainian].

32. Scribbr. Retrieved from: https://www.scribbr.com/ (Last accessed: 28.10.2023).

33. Sim, J., Wright, C.C. (2005). The kappa statistic in reliability studies: use, interpretation, and sample size requirements. *Phys Ther.*, 85(3), 257–68.

34. Retrieved from: https://www.physio-pedia.com/Star_Excursion_Balance_Test.

35. Varga, A., Révész, L. (2023). Impact of applying information and communication technology tools in physical education classes. *Informatics,* 10, 20. https://doi.org/10.3390/ informatics10010020.

36. Xu, H.-R., Zhang, Y.-H., Mao, Y., Ngo, T. L., Zhang, Q., He, G., Feng, Z. Sun, W., Wang, X.-Q. (2023). Validity and reliability of upper extremity star excursion balance test in adolescent swimmers. *Journal of Exercise Science & Fitness,* 21(2), 210–217. https://doi.org/10.1016/j.jesf.2023.02.003.

Отримано: 23.02.2024
Прийнято: 15.03.2024
Опубліковано: 29.04.2024

Received on: 23.02.2024
Accepted on: 15.03.2024
Published on: 29.04.2024