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Original Scientific Article

Determining the Reliability of Software Electronic Engineering Tools in the Control of Vestibular Disorders in Inclusive Physical Education of Studens

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Abstract

Background. Due to the increase in the proportion of mine-blast injuries sustained during the Russian-Ukrainian war, the number of students in higher education institutions after blast TBI has risen.

Objectives. The study aimed to determine the reliability of the tool for test control of gait parameters, created based on software electronic engineering for students after blast TBI in inclusive physical education.

Materials and methods. The theoretical stage of the research was realized by analyzing the literature on the studied problem, evaluating and synthesizing information from scientific sources. For the empirical part of the experiment, the Dynamic Gait Index test was used to assess gait parameters, dynamic balance, and fall risk. The test results were processed using the methods of statistical mathematical analysis. The experiment involved 30 students (men) after sustaining an explosive traumatic brain injury.

Results. The study presents the developed tool for testing gait parameters using the Dynamic Gait Index, which is based on the integration of various types of software electronic engineering services. The development uses motion, speed, pressure, and touch sensors. The information about the test exercise, recorded by the sensors, is sequentially transmitted by wireless communication means to the controller (Arduino Leonardo based on the ATmega32u4 microcontroller platform) and then to a PC, where the results are displayed on the monitor in digital and graphical form. The development uses a neural network and the Microsoft OneDrive cloud service to process information, which provides processing and storage of large amounts of test control data. The results of the empirical establishment of the Dynamic Gait Index quality measure, the characteristics of reliability and validity that were recorded by the teacher, are significantly inferior in numerical values to the correlation coefficient obtained by the results of the Dynamic Gait Index when the outcomes were recorded using the developed tool.

Conclusions. The introduction of modern software engineering services into inclusive physical education of students represents a significant step forward in implementing an impartial control mechanisms for restoring damaged gait and balance functions, which have been recognized as a leading factor in disability caused by blast TBI, and contributes to ensuring the effectiveness of this process.

Keywords: physical education, student, inclusion, blast TBI, electronic engineering, testing, control, reliability.

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Introduction

For 2.5 years in a row, russian troops have been shelling the territory of Ukraine daily. Both the military and civilians are equally likely to suffer from the war and get injured.

Due to the russian aggression, the number of people injured as a result of artillery shelling and bombardment in our country is constantly growing. According to the United Nations Human Rights Monitoring Mission (United Nations Ukraine), from 24 February 2022 to the end of June 2024, at least 33,878 civilians in Ukraine were injured in the hostilities.

Explosions cause injuries to a large number of people at the same time (Blavt et al., 2024). Therefore, mild blast-related concussion (blast TBI), along with being identified as the most common injury among military personnel (VA research on Traumatic Brain Injury), is now becoming one of the most common types of injury among civilians (Gliga, 2024).

Due to the growing proportion of mine-blast injuries during the Russian-Ukrainian war, the number of students in higher education institutions with blast TBI is increasing. The need for additional efforts and attention of higher education institutions aimed at optimizing measures to improve the outcomes for students after blast TBI determines the relevance of scientific research.

Many scientific papers are devoted to the study of students' health (Mykytyuk et al., 2022; Du et al., 2024), which is positioned as a potential of the state. As studied by (Zhytomyrskyi, 2021; Blavt et al., 2022), the problem of improving student health is one of the most important tasks of Ukrainian society has not yet been solved and needs to be addressed as soon as possible.

It has been determined (Blavt et al., 2023) that in the context of large-scale war and post-war reconstruction of the country, higher education not only performs educational functions but is also largely intended to create conditions for the implementation of inclusive policy objectives. The latter has been analyzed quite thoroughly in the scientific literature (Pérez-Gutiérrez et al., 2021; Page, Anderson, & Charteris, 2021; Iacono et al., 2021), according to contemporary narratives.

As an integral part of the process of inclusion, physical education is positioned in scientific sources (Heck & Block, 2021; Lawrence, 2018; Holland, Haegele, Zhu, & Bobzien, 2023) from the perspective of health promotion. It has been determined (Lieberman, Houston-Wilson, & Grenier, 2024; Almond, 2015; Kuntjoro, Soegiyanto, Setijono, & Suhiharto, 2022) that in higher education, physical education provides the function of improving the health of students during their studies.

It has been proved (Fulk et al., 2024) that blast TBI is not treated with medication, and underestimating the risks of this injury leads to long-term consequences, which require timely rehabilitation to avoid future consequences. The need for quality rehabilitation both during the acute period of trauma and in the process of eliminating the consequences has been studied (Ponsford et al., 2024; VA research on Traumatic Brain Injury).

Studies of the course of disorders and the body after blast TBI (Ponsford et al., 2024) indicate an individual course. It has been determined (Fulk et al., 2024) that individual control over the recovery process of these disorders is crucial to ensuring its effectiveness. Shute and Rahimi (2017) found that the appropriate use of control tools is the basis for making informed decisions in the correlation of restoration measures.

Acknowledging the key role of technology (Clara, & Qursum, 2023; Calabuig-Moreno et al., 2020) in promoting inclusive physical education, it has been highlighted (Morgulec-Adamowicz et al., 2024; Yadav, Sharma, & Kumar, 2023) the transformational potential of the latest technologies in shaping the modern progress in this field of knowledge.

The purpose of the study is to determine the reliability of the tool for test control of gait parameters, created based on software electronic engineering for students after blast TBI in inclusive physical education.

Materials and methods

Study participants

30 students after blast TBI, aged from 18 to 23 years from Lviv Polytechnic National University, T. H. Shevchenko National University "Chernihiv Colehium", Drohobych Ivan Franko State Pedagogical University and Kremenets Taras Shevchenko Regional Academy of Humanities and Pedagogy were involved in the experimental study. Each student's participation in the experiment was agreed with a medical professional after a proper medical examination. The selection of participants for the study sample was based on the principles of inclusivity, ensuring equal access to this process for all students after blast TBI.

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".

Methods

Taking into account the goal and the interdisciplinary nature of the work, its implementation involves the use of a modern algorithm for the implementation of scientific research at the theoretical and empirical levels of research.

The theoretical analysis of scientific works by leading scientists in the field and the generalization of modern specific approaches to solving a particular problem that has been implemented in practice have substantiated the identified research issues and identified ways of scientific research.

Modeling was used to develop a technical programmable design, and software engineering methods were used to develop software.

Conducting a test procedure to analyze the results of the study is the final stage of the empirical level of the pedagogical experiment. Empirical analysis and synthesis were used to record test data and analyze them.

Statistical mathematical methods were used in the process of processing the empirical results of the experiment.

The generalization of the research results provided a transition from empirical study to data processing, logical generalizations, analysis and theoretical interpretation of the factual material obtained.

In choosing the method of implementing the pedagogical experiment, we tried to select the most appropriate assessment tool after blast TBI, which is simple, accessible and at the same time, the results of which will form the basis for planning the process of restoring damaged functions and monitoring this progress. Therefore, taking into account the above, the Dynamic Gait Index (DGI) (Physiopedia) was chosen to assess functional stability during walking.

The DGI was developed as a clinical tool for assessing gait, dynamic balance, and fall risk. It assesses not only the usual steady gait but also walking in difficult conditions. (The Dynamic Gait Index (DGI) was developed as a clinical tool to assess gait, balance and fall risk. It evaluates not only the usual steady-state walking but also walking during more challenging tasks.

The test procedure involves performing the functional walking tests are performed by the subject and scored out of three according to the lowest applicable category (Physiopedia). We used a simplified version of the control with four items: stepping over and around obstacles, changing speeds and stair ascent and descent. Each item is scored on a scale of 0 to 3.

It includes eight items, walking on flat surfaces, changing speeds, turning the head in horizontal and vertical directions, walking and turning 180 degrees to stop, stepping over and around obstacles, and stair ascent and descent. The DGI was developed as a clinical tool to assess gait, balance and fall risk. It evaluates not only the usual steady-state walking, but also walking during more challenging tasks (Shirley Ryan AbilityLab).

Research organization

The organizational preparation of the research involved familiarising the students of the study sample with the testing procedure and assessment methodology. At the initial stage, students repeated the test twice. A week later, they took the test for the second time. The experimental factor was the method of fixing the results of DGI, which was implemented by the teacher and the programmable developed tool.

Before performing the DGI, the teacher carefully acquainted the students of the study sample with the procedure for implementing the test process and evaluating the results. The test results were recorded following the principles of anonymity.

Statistical analysis

The result of the statistical processing of the obtained factual material was the identification of numerical values of validity and reliability. The obtained factual material became the basis for the conclusions about the quality of the tests under study. All statistical analyses were performed using SPSS Version 24.0 (IBM Corporation).

Results

It has been shown that blast TBI can be accompanied by cognitive dysfunction, attention deficit, vestibular disorders, etc. There is evidence (Tramontano, Belluscio, Bergamini, Allevi, De Angelis, Verdecchia, Formisano, Vannozzi, & Buzzi, 2022) that most people affected by blast-related TBI experience vestibular disorders: balance and gait disorders are common symptoms after head injury. Thus, balance dysfunction has been identified as one of the most disabling aspects of TBI, especially dynamic balance during walking (Simon, & Harro, 2004).

It has been determined (Zhou, Liu, Zhang, Liu, Wang, Kong, 2021) that gait functions are provided by the complex interaction of the main body systems, such as the nervous, musculoskeletal, cardiorespiratory and vestibular systems. It has been proven that the vestibular system, which encodes signals of movement in space in the central nervous system, ensures gait stability. Therefore, given the above, our research is aimed at ensuring objective, unbiased monitoring and assessment of the state of the vestibular apparatus of students after a blast TBI.

The chosen research tool, the DGI, tests the ability to maintain balance while walking, responding to different task requirements in different dynamic conditions. The DGI is considered (Magnani, van Dieën, & Bruijn, 2023) to be a useful test for monitoring vestibular and balance disorders. It has been shown (Simon, & Harro, 2004) that the DGI is an effective tool to measure dynamic balance in individuals with brain injury. Evidence from (Chiu, Fritz, Light, & Velozo, 2006) suggests that balance assessment in multitasking conditions is a more sensitive indicator of balance development and fall risk than single-task control.

The outcome of our study was the development of a tool for testing gait parameters using DGI based on the use of software electronic engineering tools.

The development was guided by the need to control uneven movement (changing speeds), head turns in horizontal and vertical directions, walking and turning 180 degrees to stop. With this in mind, motion sensors are placed directly on the student to control the body's position in space (Mykytyuk et al., 2022).

On the obstacles required for the test (stepping over and around the obstacles), proximity and presence sensors are mounted on top and on one side of the cube-shaped obstacles. The student's movement pattern during the test process is shown in Fig. 1. The color change of the sensor signals the correct execution of the exercise, in particular, stepping over the obstacle and going around it from both sides.

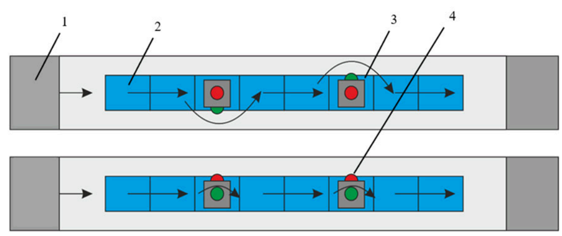

Fig. 1. Scheme of the student movement during the test process: 1 – start, 2 – direction of student movement, 3 – obstacles, 4 – sensors

Sensors placed on the obstacles allow you to automatically determine the correctness of the exercise and possible deviations. The operation of both sensors on an obstacle indicates incorrect movement, deviation from the trajectory, coordination, etc. To analyze the speed of overcoming obstacles, it is possible to place speed sensors on the obstacles.

To automate the DGI test, which involves the use of steps, pressure sensors are placed on the steps, directly on the plane (Fig. 2). In this case, they detect the moment the student steps on the step, recording full contact with the surface of the step with both feet. Receipt of two consecutive signals from the same step indicates the absence of the necessary alternation of feet provided by the test.

To determine the speed of the distance covered, speed sensors are placed on the steps. The speed sensors are placed on the steps along the sideline, and the touch sensors are placed on the handrails. The signal from these sensors, if the test subject touches the handrail during the test, will indicate the use of the handrail.

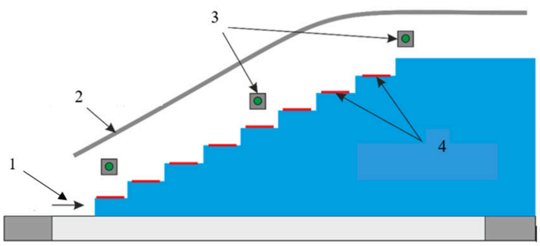

Fig. 2. Scheme of implementation of the test process with the use of steps: 1 – start, 2 – direction of student movement, 3 – touch sensors, 4 – speed sensors, 5 – pressure sensors

The implementation of DGI testing using the developed tool is as follows: motion sensors are placed on the student's body, which record information during the test exercise. The start of the test, its end and the passage of control points are recorded to the nearest millisecond.

The signal detected by the sensors is transmitted to the controller via a contactless Bluetooth data network. In our development, we used the Arduino Leonardo, a controller based on the ATmega32u4 microcontroller platform, which has 20 digital inputs/outputs and 32 kB of flash memory. The memory of this platform must be read and written using the Electrically Erasable Programmable Read-Only Memory library. This type of memory can be cleared and filled with information several tens of thousands of times. Thus, we ensure the storage and availability of student testing information throughout the entire course of study, which is stored for the required period and is available at any time.

The platform is controlled by software using an Arduino. The signal processed by the controller is sent to a PC, where, based on the results of computer calculations, we get the result in digital and graphical form on the PC screen. The development uses image analysis systems based on the latest technologies of our time – neural networks.

In our development, the neural network is used to process information, extract patterns and make decisions based on the received DGI data. We have used the ability of neural networks to work based on large amounts of data, implementing data analysis and ensuring their reliability and objectivity in real-time.

The use of the Microsoft OneDrive cloud service in the development ensured the processing and storage of significant amounts of test control data, which are available to the teacher at any time. In addition, files can be synchronized with a PC and accessed from a web browser or mobile device.

The tool works as follows (Fig. 3). Sensors are placed on the student's body. The information about the test exercise, recorded by the sensors, is transmitted wirelessly to the controller and to the PC, where the results are displayed on the monitor in digital and graphical form.

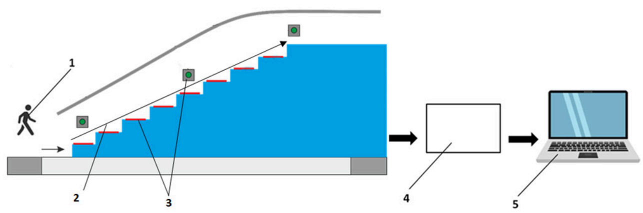

Fig. 3. Implementation of DGI testing using the developed tool: 1 – student, 2 – test distance, 3 – a system of sensors, 4 – controller, 5 – PC

The results of the empirical establishment of the DGI quality measure (Table 1), the characteristics of reliability and validity that were recorded by the teacher, are significantly inferior in numerical values of the correlation coefficient obtained from the DGI results when the results were recorded using the developed tool.

Table 1. Reliability of the DGI for students with disabilities after blast TBI (n = 30)

Statistical pparameters	Test tasks stepping and measurement results (points)							
	around obstacle		over obstacle		stairs Gait		change in gait speed	
	T	DT	T	DT	T	DT	T	DT
M	1.95	2.12	1.78	2.01	1.33	1.57	1.45	1.81
S	0.26	0.11	0.33	0.19	0.27	0.31	0.61	0.37
V (%)	31.5	20.2	29.7	21.3	33.2	20.8	32.7	18.6
	Rtt							
reliability	0.381	0.899	0.412	0.876	0.441	0.885	0.443	0.878
validity	0.211	0.605	0.242	0.617	0.285	0.641	0.227	0.626

*Note: T – registration of the results by the teacher, DT – registration of the results using the developed tool

Discussion

The powerful negative impact on public health of the Russian Federation's war in Ukraine, which has resulted in massive injuries and maims, has focused researchers' attention on the problem of health maintenance and recovery (Blavt, & Gurtova, 2024). Our study expands the information (Pérez-Gutiérrez, Castanedo-Alonso, Salceda-Mesa, & Cobo-Corrales, 2021; Heck, & Block, 2021; Lieberman, Houston-Wilson, & Grenier, 2024) on the leading role of physical education tools for students with disabilities in restoring their health.

The conducted scientific research is consistent with the scientific data (Moriña, 2016; Nilholm, 2020; Goodwino, & Watkinson, 2000) on the need for permanent changes in inclusive higher education. We support scientific approaches to the potential of inclusive physical education in implementing the above (Penney, Jeanes, O'Connor, & Alfrey, 2017; Pocock, & Miyahara, 2017; Almond, 2015).

Modern technologies in inclusive physical education are considered (Calabuig-Moreno, González-Serrano, Fombona, & García-Tascón, 2020; Almusawi, Durugbo, & Bugawa, 2021; Yu, Kulinna, & Lorenz, 2018) as a powerful catalyst that bridges gaps and creates opportunities. Such opportunities are provided by the introduction of the latest advances in unified information technology, telecommunications and software integration (Kim, Kim, Kim, Kim, Kim, & Han, 2012; Gil-Espinosa, Nielsen-Rodríguez, Romance R, Burgueño, 2022; Cabrera Ramos, Álamos Vásquez, Ariane, & Lagos Rebolledo, 2019).

The obtained scientific results expand the information (Son, Kim, Noh, Kim, Lim, & Han, 2022; Belluscio, Bergamini, Tramontano, Orejel Bustos, Allevi, Formisano, Vannozzi, & Buzzi, 2019; Ho-Dong, Eunjung, & Byoung-Hee, 2024) on ensuring the objectivity and impartiality of walking parameters control based on the integration of the latest information technologies into this process.

Our search is based on the information about the association between vestibular function and gait characteristics (Zhou, Liu, Zhang, Liu, Wang, & Kong, 2021; Magnani, Bruijn, van Dieën, & Forbes, 2021; Magnani, van Dieën, & Bruijn, 2023).

Testing of gait parameters using DGI has been applied to control in across diagnostic groups (Matsuda, Taylor, & Shumway-Cook, 2014), middle-aged patients with stroke (Jin, Lee, Park, Lee, & Lim, 2023), children (Lubetzky-Vilnai, Jirikowic, & McCoy, 2011), with cerebellar ataxia (Reoli, Therrien, Cherry-Allen, Keller, Millar, & Bastian, 2021), patients with normal pressure hydrocephalus for cerebrospinal fluid diversi (Chivukula, Tempel, Zwagerman, Newman, Shin, Chen, Gardner, McDade, & Ducruet, 2015).

The reliability of the DGI has been studied for different groups of people, including people with chronic stroke (Jonsdottir, & Cattaneo, 2007; Alghadir, Al-Eisa, Anwer, & Sarkar, 2018), vestibular disorders (Wrisley, Walker, Echternach, & Strasnick, 2003; Marchetti, Lin, Alghadir, & Whitney, 2014), and brain injury (Simon, & Harro, 2004; Belluscio, Bergamini, Tramontano, Orejel Bustos, Allevi, Formisano, Vannozzi, & Buzzi, 2019), in older men (Abdiani, Golpayegani, & Khajavi, 2014), male veterans (Chiu, Fritz, Light, & Velozo, 2006), with hemiparesis after stroke (Flansbjer, Holmbäck, Downham, Patten, & Lexell, 2005), with multiple sclerosis (Soltanpour, Kalantari, & Roostaei, 2019).

We first investigated the use of DGI to assess the state of gait and balance parameters and determined the level of reliability for students after blast TBI, which is the basis for ensuring impartiality and objectivity of control in the physical education of students after blast TBI.

Conclusions

Implementing an inclusive educational process for students affected by war is a challenge for higher education institutions. Even though the war is ongoing, the need to implement a set of measures aimed at protecting the health of participants in the educational process is due to the permanent increase in the number of students who have sustained war-related injuries, including blast TBI, in higher education institutions.

In the case of blast-related injuries, it is important to understand the vestibular consequences of blast TBI, as blast TBI is very typical of modern wars, particularly the Russian-Ukrainian war. Our research is based on the fact that gait and balance dysfunction is recognized as a leading factor in disability after blast TBI. It has been found that the introduction of modern technological solutions for the implementation of impartial control of the process of restoring damaged functions is a factor in ensuring the effectiveness of this process.

The article presents the developed constructive solution, which is implemented on the basis of software electronic engineering, providing processing of large arrays of data obtained from the test results, and, thanks to cloud services that implement high-speed computing, makes it possible to obtain objective, unbiased test control results in real-time.

The reliability of the developed design for the control of vestibular disorders in inclusive physical education of students after blast TBI was established at the level that, according to the evaluation scales, is 'high' in terms of reliability and validity. These results significantly exceed the established values of test-retest reliability when the results are recorded directly by the teacher.

Conflicts of Interest

No conflicts of interest exist.

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Визначення достовірності інструментів програмної електронної інженерії у контролі вестибулярних розладів у інклюзивному фізичному вихованні студентів

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 9 с., 1 табл., 3 рис., 59 джерел.

Через зростання питомої ваги мінно-вибухових поранень під час російсько-української війни, збільшується чисельність студентів у закладах вищої освіти після після вибухової черепно-мозкової травми.

Мета статті полягала у визначені достовірності інструменту тестового контролю параметрів ходи, створеного на основі програмної електронної інженерії для студентів після після вибухової черепно-мозкової травми у інклюзивному фізичному вихованні.

Матеріали та методи. Теоретичний етап дослідження реалізовано аналізом літератури з досліджуваної проблематики, аналізом та синтезом інформації наукових джерел. Для реалізації емпіричної частини експерименту використано тестування з використанням Dynamic Gait Index для оцінки параметрів ходи, динамічної рівноваги та ризиків падіння. Результати тестування опрацьовано методами статистичного математичного аналізу. До експерименту залучено 30 студентів (чоловіки) після вибухової черепно-мозкової травми.

Результати. Представлена розроблена конструкція для тестування параметрів ходи з використанням Dynamic Gait Index, що ґрунтується на інтеграції різноманітних видів сервісів інструментів програмної електронної інженерії. У розробці використано сенсори руху, швидкості, тиску та дотику. Інформація про виконання тестової вправи, зафіксована сенсорами, передається бездротовими засобами зв'язку послідовно на контролер (Arduino Leonardo на базі мікроконтролерної платформи ATmega32u4) та далі на персональний комп'ютер, де результати представляються на моніторі у цифровому та графічному вигляді. У розробці для обробки інформації, використано нейромережа та хмарний сервіс Microsoft OneDrive, яким забезпечують обробку та зберігання значних обсягів даних тестового контролю.

Результати емпіричного установлення міри добротності Dynamic Gait Index, з'ясовані характеристики надійності та валідності, які реєструвались викладачем, значно поступаються у числових значеннях коефіцієнту кореляції, який отримали за результатами Dynamic Gait Index у разі, коли результати реєструвались з використанням розробленої конструкції.

Висновки. Упровадження сучасних технологічних рішень задля реалізації неупередженого контролю процесу відновлення ушкоджених функцій ходи та рівноваги, що визнана провідним фактором інвалідизації після blast TBI, є чинником забезпечення ефективності інклюзивного фізичного виховання студентів.

Ключові слова: фізичне виховання, студент, інклюзія, вибухова черепно-мозкова травма, електронна інженерія, тестування, контроль, достовірність.

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