Using Programmable Device Installations to Control Students with Disabilities after Blast Traumatic Brain Injury in 10 Meter Walking Test

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Abstract

Objectives. This study aimed to determine the degree of authenticity for the test implemented using a programmable installation for monitoring the functions of functional mobility, gait, and the state of the vestibular apparatus in students with disabilities who have sustained a blast traumatic brain injury.

Material and methods. The study included a total of 39 first-year students with disabilities after an explosive brain injury. The following methods were used: theoretical analysis of scientific and methodological literature, the method of technical modelling, pedagogical testing, pedagogical experiment, and methods of mathematical statistics. In order to ascertain the efficacy of the proposed intervention, a 10-meter walking test was conducted.

Results. The result of our study was the development using information systems and networks of a programmable device for the implementation of the 10-meter walking test, which is used to monitor the recovery of functional mobility, gait, and the state of the vestibular apparatus in students with disabilities after an explosive brain injury. The installation was based on a network of sensors organized according to the Arduino microcontroller platform. Acoustic, optical sensors, distance sensors, proximity sensors, presence sensors, and spatial position sensors have been placed to record the results of the test distance. The sensors, having received an information signal about the student passing the test, transmit it to the controller. In the controller, information is identified, processed, calculated and transferred to a personal computer, where it is displayed on the screen and reproduced graphically. The software ensures maintainability throughout the test, as well as efficiency of data processing, calculation of required parameters and their storage. Data processing is implemented using image analysis systems based on neural networks. According to the findings of testing and correlation analysis, indicators' authenticity degree for the used tests were established, which differed by the means of measuring the results. The level of correlation coefficient between the values for test reliability and validity in the case of fixing the test results using a stopwatch was not found to fall within the “low” and “acceptable” limits, while in the second case, when the results were fixed by a programmed control unit, it reached the “high” level.

Conclusions. The use of the developed programmable device in the practical work of inclusive PE provides convenience, functionality, objectivity and reliability of control in the process of rehabilitation of students with disabilities after an explosive craniocerebral injury. What is confirmed by the values of the test authenticity measure obtained during the experiment when fixing the results by the developed installation.

Keywords: students with disabilities, blast traumatic brain injury, physical education, testing, inclusion, control, authenticity.
Introduction

From February 24, 2022, Russia’s full-scale aggression against Ukraine continues. In addition to protracted hostilities, the aggressor’s army is shelling the civilian population daily. As a result, the number of people, including military personnel, children, and civilians, affected by the aggression of the Russian Federation with war injuries is permanently increasing (Dzyak et al., 2023).

Despite the lack of accurate statistical data for the period of the war in Ukraine, Ukraine has not yet encountered such a large number of complex injuries. Injuries as a result of war are characterized by considerable diversity, but according to data, 99% of victims have mine-explosive injuries, among which brain injuries are considered the most complex – blast traumatic brain injury (TBI) (U.S. Department of Veterans Affairs. Office of Research and Development, Veterans Health Administration, 2007).

According to (Chapman & Diaz-Arrastia, 2014), the number of blast TBI from blast wave action, which has no analogs in the clinic of peacetime diseases, is astounding. According to evidence (Mac Donald et al., 2014), among all injuries received during the war: 35-40% are head injuries, of which 80% is blast TBI. According to data (VA research on Traumatic Brain Injury, 2019), the majority of blast TBIs associated with military actions and received by civilians are classified as mild.

Due to the fact that individuals with disabilities due to blast TBI are becoming students in increasing numbers, the higher school has found itself at the epicenter of serious challenges. The need to provide conditions for the restoration of the health status of students with disabilities after blast TBI in the process of education is growing due to the challenges of the long war, which determines the relevance of scientific intelligence.

The problem of improving the health status of students with disabilities after blast TBI becomes especially urgent given the fact that the timely restoration of the functions is a factor in preventing physical maladaptation of such students and ensuring the further ability to effectively perform their professional activities (Blavt, Iedynak, Pereverzieva, Holub, & Melnyk, 2023). It has been studied (Pellerin, Wilson, & Haegele, 2022; Blavt, Chaplinskiy et al., 2023).

There is a large list of studies on the feasibility and necessity (given the need to eliminate the influence of the human factor) of using information systems and networks, created on the basis of electronic technologies that are used in the PE process (Mykytyuk, Blavt et al., 2022; Varga & Révész, 2023; Gupta, 2021).

*Purpose of the research* is a determination of the degree of authenticity of the test implemented using a programmable installation for monitoring the functions of functional mobility, gait, and the state of the vestibular apparatus in students with disabilities after blast TBI.

Materials and Methods

Research Methods

The conducted research belongs to the randomized controlled type of empirical research. The experiment was implemented in two stages. The following methods were used: theoretical analysis of scientific and methodological literature, the method of technical modeling, pedagogical testing, pedagogical experiment, and methods of mathematical statistics.

The first stage consisted in the development of a programmable control unit using information systems and networks. For this, the method of technical modeling was used.

The second stage involved the implementation of a pedagogical experiment. The experiment consisted in the implementation of pedagogical testing, during which the control of functional mobility, gait, and the state of the vestibular apparatus (to determine functional mobility, gait, and vestibular function) was implemented in students of the studied sample.

The 10 Meter Walk Test was used in the study (Gafner, & Bruyneel, 2022). The appropriateness of choosing this test was that its use provides ease of control and assessment of measuring locomotor capacity in clinical and research settings (to measure locomotor capacity in clinical and research settings (de Baptista et al., 2020) which are recommended for monitoring the rehabilitation process for various diseases (Unver et al. 2017).

It is considered (Physiopedia), the scale properties (time in seconds or m/s) of the 10 Meter Walk Test make it a responsive test well suited to evaluating clinical interventions.

Test procedure. Equipment Required: a clear pathway with a set distance (6, 8, or 10 meters in length depending on distance tested). The student must walk 10 meters unaided, with the intervening 6 meters timed to account for acceleration and deceleration (Fig. 1). The time is recorded (to the nearest second) and the walking speed is calculated.

Fig. 1. Scheme of the test
The student walks without assistance for 10 meters, with the time measured for the intermediate 6 meters to allow for acceleration and deceleration. Perform three trials and calculate the average of three trials. Scoring: The time (to the nearest second) is fixed.

Study Participants

39 students in the 1st year of studies with disabilities as a result of the blast TBI, were involved in the study from Lviv Polytechnic National University, Kamianets-Podilskyi Ivan Ohienko National University, Lviv State University of Physical Culture named after Ivan Boberskyi and Lutsk National Technical University.

To implement the empirical part of the study, a research sample was formed. The selection of students for the experiment was randomized, taking into account personal consent to the collection and systematization of control information in an anonymized form for further statistical analysis. The gender factor was not taken into account, since no evidence of the influence of gender has been found on the quality indicators of the test.

The criteria for inclusion in the studied sample were the presence of the anamnesis of students with mild blast TBI disability, obtained as a result of the war, and being in a state of restoration of lost functions. The criteria that did not allow students with disabilities after blast TBI to participate in the study were the presence in the anamnesis of deformities and diseases affecting walking, the inability to move without aids (crutches, walking sticks), the presence of chronic health conditions and combined injuries.

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

A comparative pedagogical experiment was carried out to determine the effectiveness of the means of control. As an experimental factor, a means of registering the results was used. In the first case, the registration of the results took place using a stopwatch and was carried out by the teacher.

Average time and speed of the walk (10 m) and midwalk (6 m) obtained at a self-selected fast pace were analyzed. Participants were tested on the 10MWT twice: at baseline (test) and after seven days (retest). The outcome variable was the time taken to complete the test.

As a result, the registration of the results was performed using programmable installations, which ensured the calculation of the average arithmetic value of three attempts used in the conclusions.

On the contrary, in the second case, the registration of the results took place using the programmable installation developed during the research, which ensured the calculation of all the necessary parameters automatically.

Statistical Analysis

Statistical analysis was used as a data analysis tool in our study. The obtained data from such an analysis became the basis of substantiated conclusions of the study of the degree of authenticity of the used test. In our case, such data served as the intraclass correlation coefficient, which is an indicator of the quality characteristics of the test as a measurement tool, namely its reliability and validity values. Intraclass correlation coefficient determined by correlation analysis.

All statistical analyses were performed using SPSS Version 22.0 (IBM Corporation).

Results

First of all, our experiment is based on the characteristics of blast TBI and the consequences for the body that accompanies it. It should be taken into account that BI, which occurs as a result of the action of a mine blast wave and has received the name blast TBI, is significantly different from that which occurs as a result of the action of other factors (impact, sports injuries, etc.) (Denby et al., 2020; Capizzi Woo & Verdugo-Gutierrez 2020).

Understanding the mechanisms of blast overpressure injury is important to finding ways to repair it (Nelson, Davenport, Sponheim, & Anderson, 2015). Therefore, in the PE process, it is necessary to take into account the impact of blast TBI on numerous vital functions, which can have a significant long-term impact on health (Bryden, Tilghman, & Hinds, 2019), since blast TBI is described as a chronic health condition (Haarbauer-Krupa, Pugh, Prager, Harmon, Wolfe, & Yaffe, 2021).

The peculiarity of blast TBI is that it can be accompanied by damage to the auditory and vestibular apparatus (Denby et al., 2020) and lead to a persistent vegetative state of disturbance in the activity of the central nervous system (Mac Donald et al., 2014). The result of such lesions is a motor deficit, consisting of a violation of body balance (DePalma, 2015), and a long-term motor deficit (Bramlett, & Dietrich, 2015). The result is a loss of stability and balance during walking and other locomotor movements (getting out of bed, chair, etc.) (Corwin et al., 2015).

Therefore, to ensure the efficiency and speed of recovery, specialists (Briskin, Odinets & Pityn, 2015) focus their attention on finding ways to effectively control this process, as a result of which tests become more and more diverse and complex to implement best practices for timeliness of intervention, monitoring and evaluation states after blast TBI (Haarbauer-Krupa et al., 2021).

The result of our research was the development, using information systems and networks, of a programmable installation for monitoring the restoration of functional mobility functions, gait, and the condition of the vestibular apparatus in students with disabilities after blast TBI.

The basis of the installation (Fig. 2) (Mykytyuk et al., 2024) was a sensor network organized based on the
Arduino microcontroller platform. Acoustic, optical, range, proximity, presence, and spatial position sensors are placed to record the test distance results (Mykytyuk, Blavt et al., 2022), which have different purposes in our installation. However, all sensors are assembled in a set, united by a common program for storing, processing, and displaying test data on a personal computer.

Sensors are placed at control points to record the beginning of the test process, the intermediate 6 meters, and the end of the test. In this way, it is possible to record whether a student walks 10 meters, without outside help, without losing balance, and at a constant speed. The determination of the time of movement between points is provided by the developed software.

A “smart system” with optical sensors is built into the device to measure the student’s position in space when performing a test exercise that assesses the state of functional mobility and balance while walking. Such a system, with the help of a neural network, analyzes the position and movements of the student during the test and automatically records all the studied parameters and the presence of deviations from the norm.

In the developed installation, sensors are placed directly on the student’s body. In this way, we ensure the reliability of the measurement of all parameters of coordination, balance, and functional mobility. A feature of the developed software installation is that such measurements can be carried out without sensors located at control points of the test distance.

The sensors, having received an information signal about the student passing the test, transmit it to the controller. In the controller, information is identified, processed, calculated, and transferred to the personal computer (PC). On a PC, the test results are displayed on the screen and reproduced graphically.

The software implements maintainability throughout the test, efficiency of data processing, calculation of necessary parameters, and storage. Data processing is implemented using image analysis systems based on neural networks.

The second stage involved the implementation of a comparative pedagogical experiment. According to the results of testing and correlation analysis (Table 1), indicators of the degree of authenticity of the used tests were established, which differed in the means of measuring the results.

**Table 1. Degree of authenticity of the 10 Meter Walk Test for students with disabilities after blast TBI (n = 39)**

<table>
<thead>
<tr>
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<th>S</th>
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<th>S</th>
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</thead>
<tbody>
<tr>
<td>reliability</td>
<td>0.588</td>
<td>0.891</td>
<td>0.611</td>
<td>0.922</td>
<td>0.594</td>
<td>0.912</td>
<td>0.591</td>
<td>0.933</td>
<td></td>
</tr>
<tr>
<td>validity</td>
<td>0.215</td>
<td>0.218</td>
<td>0.616</td>
<td>0.609</td>
<td>0.220</td>
<td>0.618</td>
<td>0.223</td>
<td>0.601</td>
<td></td>
</tr>
</tbody>
</table>

* Note: S – fixing the results with a stopwatch, PI – fixing the results with a programmable installation

The level of the correlation coefficient of the values of test reliability and validity in the first case (fixing the results with a stopwatch) was not at the limit of “low” and “acceptable”, in the second case (fixing the results with a programmable installation for monitoring) it reached the level of “high”.

**Discussion**

Before the war, the issue of inclusion attracted considerable attention, however, as a result of the war, the issue of inclusive PE in higher education, given the humanitarian trends during emergencies (Congressional Research Service, 2019), gained special importance. The research conducted extends the data of previous studies (Blavt, Bodnar et al., 2023; Blavt, Iedynak et al., 2023) that the evolution of inclusive PE to meet the challenges of today, which are caused by Russia’s long-term aggression against Ukraine requires the search for innovative solutions to ensure proper conditions for recovery after injuries of students with disabilities.

Researchers see the solution to this issue in constructive and technological solutions based on the use of modern information technologies (Varga & Révész, 2023; Gupta, 2021; Cuthbert et al., 2014), which is currently is the most dynamic segment of software engineering development.

The effects of blast TBI remain a serious source of injury for armed forces and civilians in combat zones worldwide (Xiang et al., 2022). Blast injuries have been identified as a new entity with specific characteristics. Blast injuries have been identified as a novel entity with specific characteristics (Maas et al., 2008; Merritt et al., 2015). Physical activity is considered by experts as a powerful means of non-pharmacological recovery after blast TBI (Physical Activity Guidelines for Traumatic Brain Injury; Fulk & Nirider, 2014;
Johnson et al., 2023), control, as proven (Bland et al., 2011; Fure et al., 2021), having an exploratory and evaluative nature, is the basis of evidence-based rehabilitation. The need for such studies is due to the lack of randomized trials in the rehabilitation of students with disabilities after blast TBI (Xiang et al., 2022).

Tests that use the function of walking are quite widespread in the practice of monitoring the rehabilitation process in persons with amputations (Brooks et al., 2001), cardiovascular diseases (Bellet et al., 2012; Hanson et al., 2012; Casillas et al., 2013), with total hip arthroplasty (Yuksel et al., 2021), brain injuries (SCIRE-PROJECT), in muscular dystrophy (Pizzato et al., 2016), in neurological diseases (Tyson & Connell, 2009) and even in children, during their development (de Baptista, et al., 2020).

A certain list of works is devoted to the determination of quality indicators of tests using walking for a certain distance in relation to various studied contingents. In particular, young healthy adults (Smith-Turchyn et al., 2021), persons with total hip arthroplasty (Yuksel et al., 2021), in typically developing children (de Baptista et al., 2020), persons with lower limb prostheses (Sawers et al., 2020). However, studies on the use of walking tests for students with disabilities after blast TBI have not yet been conducted.

On the other hand, we agree with our research on the use of test results to monitor the progression of disability. This was confirmed by previous studies (Pizzato et al., 2016).

The results of our previous research on the expediency of using technical means in the implementation of the control process in inclusive PE have been supplemented. Considering that specialists recommend repeating the test after certain periods (Pizzato et al., 2016), the developed setup makes it possible to implement such control with the least loss of time.

Conclusions

Inclusive PE in times of war faces new challenges. As a result of the armed aggression of the Russian Federation, due to shelling and explosions, the structure of the contingent of students with disabilities was significantly affected: now students with disabilities after blast TBI are the largest contingent.

Blast TBI is considered a problem that goes beyond the scope of BI and is positioned as a multiple injuries, which allows us to assert the objectivity of the control of the studied parameters.

Conflicts of Interest

No conflicts of interest exist.

References


**Physiopedia: 10 Metre Walk Test. Available at:** https://www.physio-pedia.com/10_Metre_Walk_Test


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SCIREPROJECT Available at: https://scireproject.com/about-scire-project/


Застосування здобувачами вищої освіти з інвалідністю після вибухової черепно-мозкової травми установки для контролю у 10-метровому тесті ходьби

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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., 55 джерел.

Мета дослідження – визначити ступінь автентичності у 10-метровому тесті ходьби, реалізованого з використанням розробленої програмованої установки контролю відновлення функції функціональної рухливості, ходи та стану вестибулярного апарату у здобувачів вищої освіти з інвалідністю після вибухової черепно-мозкової травми.

Матеріал та методи. 39 студентів І курсу з інвалідністю після вибухової черепно-мозкової травми. Використано такі методи: теоретичний аналіз науково-методичної літератури, метод технічного моделювання, педагогічне тестування, педагогічний експеримент, методи математичної статистики. У дослідженні застосовано 10-метровий тест ходьби.

Результати. Результатом нашого дослідження стала розробка з використанням інформаційних систем та мереж програмованої установки для реалізації 10-метрового тесту ходьби, який застосовується в процесі реабілітації здобувачів вищої освіти з інвалідністю після вибухової черепно-мозкової травми. Основою установки стала мережа сенсорів, яку організували на базі мікроконтролерної платформи Arduino. Для фіксації результатів досягнуто відновлення тесту було розміщено акустичні, оптичні, датчики дальності, наближення, присутності та положення у просторі. Датчики, отримавши інформаційний сигнал про проходження тесту, передають його на контролер. У контролері інформація індифікується, обробляється, обчислюється та передається на персональний комп’ютер. Програмне забезпечення реалізує супроводження впродовж усього тесту, ефективність обробки даних, обчислення необхідних параметрів та інше.

Висновки. Використання у практичній роботі інклюзивного фізичного виховання здобувачами вищої освіти з інвалідністю після вибухової черепно-мозкової травми забезпечує зручність, функціональність, об’єктивність та достовірність контролю у процесі реабілітації здобувачів вищої освіти з інвалідністю після вибухової черепно-мозкової травми.

Ключові слова: здобувачи вищої освіти з інвалідністю, вибухова черепно-мозкова травма, фізичне виховання, тестування, інклюзія, контролю, автентичність.

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