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Original Scientific Article

Restoration of Lost Functions in Students after Blast Traumatic Brain Injuries in the Process of Inclusive Physical Education

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Abstract

Background. It has been determined that the main task of higher education today is to solve the problem of providing students who have been injured as a result of war with opportunities along with higher education and rehabilitation conditions.

Objectives. The purpose of the article is to determine the effectiveness of the developed program of inclusive physical education on the restoration of dynamic balance functions in students after blast traumatic brain injury.

Materials and methods. The research combined theoretical (analysis, synthesis, generalization) and empirical methods (pedagogical experiment, testing). Testing was realized using the Dynamic Gait Index and the method of stabilization. The experiment, which was realized during the academic year in the academic course of physical education, involved 30 male students after explosive traumatic brain injury, provided there were no complications.

Results. The developed program of inclusive physical education after blast traumatic brain injury is presented. The content of the program is aimed at providing maximum opportunities for differentiation of the educational process and implementation of an individual approach in its implementation. The results of the test control of students of the studied sample before the beginning of classes testified to significant deviations in the state of the studied parameters. According to the evaluation of the obtained control data, the studied indicators did not reach the level of «average», which is a consequence of the influence of blast traumatic brain injury on the state of dynamic balance and gait parameters. The final testing showed a difference in the studied parameters in response to the implementation of the proposed innovations. A statistically significant improvement was observed in determining the progress and effectiveness of the studied parameters of gait and balance in the range of 10-19.6 %.

Conclusions. For the first time, we have implemented a study of students after blast traumatic brain injury, in which we directly controlled the violation of dynamic balance and gait in inclusive physical education. The results obtained are evidence that strategies and approaches will be effective, efficient and lead to the desired result in the case of improving practical methods to develop a reliable evidence base.

Keywords: inclusion, physical education, student, balance, gait, blast traumatic brain injury.

Introduction

As a result of the full-scale invasion of russia and the ongoing aggression of the russian federation on the territory of Ukraine, the frequency of blast traumatic brain injuries (TBI) among the population has increased dramatically. Since the main causes of blast TBI, along with combat injuries, are injuries caused by rocket attacks and bombardments, civilians, accurate statistics for the period of war in Ukraine are currently unavailable.

Meanwhile, TBI is now recognized as the most common type of traumatic injury, a cause of morbidity and mortality (Aida, Chau, & Dunn, 2018) and disability (25-30%) worldwide (Ponsford et al., 2024). According to the WHO, the number of TBIs increases by an average of 2% annually, and in Ukraine, due to active hostilities, the rate of 120 thousand cases per year has doubled (Dzyak et al., 2023), which is also a factor in the health crisis (Ling, & Ecklund, 2011).

Given the multidisciplinary nature of the problem (Dzyak et al., 2023), higher education is also at the epicenter of the identified issue, as people after blast TBI join the ranks of students every year. Therefore, the main task of higher education in the short term is to solve the problem of providing students with war-related injuries with opportunities for rehabilitation along with education (Blavt, & Gurtova, 2024).

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The issue is particularly relevant due to the high proportion of blast TBI among students, which, in the absence of rehabilitation measures, leads to serious functional impairment (Roby et al., 2024). This problem is also gaining relevance from an economic point of view, as students after blast TBI are people of working age who may eventually acquire the status of "person with a disability" (Misyura, 2023).

Analysis of recent research and publications. The literature indicates that despite the fact that mild TBI (mTBI) can lead to debilitating symptoms (Ganti et al., 2019), the damage can be hidden, and the body's compensatory functions ensure vital activity, the need for rehabilitation measures is recognized by scientific research (Fulk et al., 2024; Blavt et al., 2024; Denby et al., 2020).

TBI occurs when external physical forces impact the head sufficiently to cause brain damage (Rauchman et al., 2023). It has been shown (Tramontano et al., 2020; Vander Vegt et al., 2023; Pérez-Rodríguez et al., 2021), that mTBI can cause long-term central nervous system disorders, loss of coordination, and other serious complications. In particular, studies (Klima et al., 2019; Hoffer, & Balaban, 2018) indicate that TBI injuries result in both cognitive and neuromuscular deficits. In particular, deterioration of vestibular coordination and gait (Dever et al., 2022) is recognized as one of the main consequences of blast TBI and a common impairment in individuals with post-traumatic brain injury (Harris et al., 2023).

Therefore, balance deficits have been identified as a factor limiting productive participation in social life (Alashram et al., 2020; Kiliç, Çelikyurt, & Algun, 2023) and education (Blavt, & Gurtova, 2023). Balance impairment is studied in terms of the need for rehabilitation interventions to correct gait (Marchetti, & Whitney, 2006), or a combination of gait and balance interventions in TBI rehabilitation (Bland et al., 2011; Rauchman et al., 2023) to improve quality of life (Joyce et al., 2022; Roby et al., 2024). It has been studied (Aligene, & Lin, 2013) that vestibular rehabilitation therapy prevents the progression of neurological complications of TBI and prevents the development of severe complications in the future.

In higher education institutions, physical rehabilitation is implemented in the process of an academic course of inclusive physical education (PE) (Blavt et al., 2023). Inclusion in education, which is the elimination of isolation in this process, is the subject of a wide range of research (Holland et al., 2023; Graham, 2023; Lieberman, Houston-Wilson, & Grenier, 2024). Instead, it is argued that PE has significant opportunities in the process of restoring the state of damaged functions of students with disabilities (Barber et al., 2024).

Meanwhile, despite the critical importance of inclusive PE in counteracting modern challenges to the impact on students' psychophysical state, this issue is rather narrowly considered in the national scientific discourse. Even though in recent decades, the latest approaches aimed at avoiding or minimizing complications have been introduced into the practice of physical rehabilitation, the issue of rehabilitation of students after blast TBI is practically not discussed in the national scientific literature, especially given the impact of current military events in Ukraine.

Therefore, recovery after blast TBI as a prolonged process (Tefertiller et al., 2019) is of great practical importance, as it allows us to determine the validity of the rehabilitation approaches used as components of a comprehensive recovery process that can prevent the progressive course of the injury (Fulk et al., 2024; Ganti et al., 2019).

Therefore, the restoration of lost body functions as a result of blast TBI in students in the process of inclusive PE deserves special attention and careful study to make the necessary adjustments to this process, taking into account the results of empirical studies, which currently remain limited. Ultimately, the findings will contribute to improved curricula and, consequently, to the effectiveness of the process of restoring lost functions due to war trauma in students with disabilities. Here we note the almost complete lack of research and recommendations on the modification of inclusive PE as a means of restoring the functions of the lost as a result of after blast TBI, especially taking into account the impact of modern military events in Ukraine.

Ensuring the recovery of body functions lost as a result of military injuries of the limbs in students with disabilities deserves special attention and careful research to make the necessary corrections in this process, taking into account the results of empirical studies. As a result, the obtained results will contribute to the improvement of educational programs, and, therefore, to the effectiveness of the process of restoration of lost functions due to war injuries in students with disabilities.

Ensuring the recovery of body functions lost as a result of military injuries of students deserves special attention and careful research to make the necessary corrections in this process, taking into account the results of empirical studies. As a result, the obtained results will contribute to the improvement of educational programs, and, therefore, to the effectiveness of the process of restoration of lost functions due to war injuries in students.

The purpose of the article to determine the effectiveness of the developed program of inclusive PE on the restoration of dynamic balance functions in students after blast traumatic brain injury blast TBI.

Material and Methods

Study Participants

30 students after blast TBI in the 1st year of study from Lviv Polytechnic National University, Drohobych Ivan Franko State Pedagogical University, H. Shevchenko National University "Chernihiv Colehium" and Taras Shevchenko Regional Humanitarian-Pedagogical Academy of Kremenets were involved in the experimental study.

The representativeness of the sample of participants was ensured by selecting students after a blast TBI sustained as a result of war. The possibility of involving students in the trial was certified by a medical professional who made a decision based on an assessment of the criteria for inclusion or ineligibility. Namely, control of their health status, absence of complications and contraindications.

The experiment was conducted exclusively with the anonymous written consent of the students. Students who agreed to participate in the study were given the right to withdraw from it at any time during the study, weighing the benefits and risks for themselves.

The study was planned and carried out following the principles of bioethics set forth by the World Medical As-

sociation (WMA–2013) in the Helsinki Declaration "Ethical Principles of Medical Research Involving Humans" and UNESCO in the "General Declaration on Bioethics and Human Rights".

Design of the Study

The guiding principle in the choice of research methods, which is one of the key stages in the process of scientific research, was their reliability, which ensured the receipt of empirical data obtained by testing the hypothesis (Ivashchenko, 2020). For a more complete understanding of the problem, theoretical (analysis, synthesis, generalization) and empirical (pedagogical experiment) methods were used in combination. The systematization of scientific research was used to collect, analyze, and interpret data.

The pedagogical experiment included control tests. Tests designed to control balance usually consist of static and dynamic tasks (Gawronska et al, 2023). The choice of the test program was based on limited resources, including time, the need for a comprehensive assessment, and certain advantages, such as ease of implementation and interpretation. Therefore, the Dynamic Gait Index (DGI) (Physiopedia) was used to evaluate our study based on the detection of balance dysfunction and gait measurement in people with balance and vestibular disorders. Its scoring system provides clear insights into a patient's functional abilities.

The DGI procedure involves performing the functional walking tests are performed by the subject and scored out of three according to the lowest applicable category (Physiopedia). DGI it evaluates not only the usual steady-state walking, but also walking during more challenging tasks (Shirley Ryan AbilityLab).

Our study used the following items: stepping over and around obstacles, changing speeds, gait and pivot turn and stair ascent and descent, walking speed. Average walking speed = total distance travelled (m)/average time (s). It generally takes about 15 minutes to complete the 8 tests in the DGI (Physiopedia). A stopwatch was used as a time measurement tool.

Each item is scored on a scale of 0 to 3 with higher numbers indicating better performance of the specified task. Additionally, each item has specific criteria that must be met to be granted a specific score number. The test has a total score out of 24 (Marchetti & Whitney, 2006).

The method of stabilometry was implemented by the «Stabilan 01-2» stabilizer. It was used to establish the state of balance and maintain the center of gravity of the body. Each student in the study sample performed three attempts. The arithmetic mean of the three trials was used in the analysis. On the stable platform of the stabilograph, the subjects arbitrarily maintained an upright body position.

The level of balance development was determined by the coefficient of balance development (CBD, %), which is the minimum rate of change of the center of mass (CM), reflecting the degree of stabilokinetic resistance of the body to mass movement in the sagittal and frontal planes.

Research Organization

The comparative pedagogical experiment was conducted according to the plan over two academic semesters. The plan contains information about each student in the study sample, a lesson plan, and a schedule for conducting control tests. The use of modern data archiving technologies ensured the protection of personal data and the safety of the students in the study sample.

Before the study, students were informed about its content, and the criteria for evaluating test results were clearly defined and agreed upon. The first stage of testing was conducted before the start of classes, and the second – at the end of the second semester. The criterion for the effectiveness of the study was the dynamics of the parameters under investigation. The evaluation was implemented taking into account the recommendations (Middleton, Fritz, &Lusardi, 2015).

Statistical Analysis

Statistical analysis was used as a tool for analysis, data systematization and automated reporting, which was implemented using the SPSS Version 24.0 mathematical calculation package (IBM Corporation). Statistical information is expressed in descriptive statistics. The arithmetic mean(X) ± standard deviation (S) for each of the measurements was used as a generalizing characteristic. The median (Me) as an indicator of the central tendency. To assess differences, the difference between the measurements before and after was determined, and the Student's t-test was calculated. Differences were considered significant at $p < 0.05$-0.001.

Results

It has been determined (O'Sullivan, Schmitz, & Fulk, 2019) that physical rehabilitation is an important stage of recovery that results in the return of physical fitness lost due to injury. In the context of our research, recreational walking is recognized as an important component of rehabilitation for a wide range of diseases (Rapp et al, 2015), including blast TBI. The connection between gait speed and strength, mobility of nervous processes, hand function, daily activities, and maintenance of dynamic stability has been recognized (Schniepp, Möhwald, & Wuehr, 2017). At the same time, the potential of gait as a tool for reliable clinical assessment of the functional status of vestibular disorders has been investigated (Schmid et al, 2007), and balance control is a widely used tool in the management of BI (McKee et al, 2024).

Therefore, our empirical study is based on the fact that gait rehabilitation is part of the rehabilitation program for people with BI (Moseley et al, 2004) and is widely used to monitor the recovery of damaged functions (Van Loo et al, 2004; Middleton, Fritz & Lusardi, 2015).

The experiment involved the implementation of a rehabilitation program for the damaged functions of the students' bodies after blast TBI. The rehabilitation program was considered by us as a necessary basis for the formation and transformation of existing practices of inclusive PE. The expedient clear use of best practices from many sources ensured the effectiveness of the program. Its characteristic feature is the synthesis of diverse influences that complement and reinforce each other and are generally aimed at achieving its main goal - improving vestibular coordination and balance development.

Based on the position of a multidisciplinary approach and the implementation of continuous monitoring, the pro-

Table 1. Results of test control

Variables		Test tasks and measurement results										
		at the beginning of the experiment					after of the experiment					
		X	S	As	Me	V	X	S	As	Me	V	effect %
Gait level surface 10 м (s)		9.11	0.19	0.44	8.89	27.7	8.17	0.37	0.35	8.09	29.1	18.2
Around obstacle		1.95	0.26	0.03	1.88	31,5	2.35	0.33	0.07	2.28	28.3	16.2
Velocity (м/с)		1.09	0.16	0.02	0.97	26.7	1.22	0.11	0.02	1.18	26.7	15.9
Over obstacle		1.78	0.33	0.07	1.81	29.7	2.03	0.27	0.04	1.95	30.2	13.6
Stairs Gait		1.33	0.27	0,12	1.29	33.2	1.67	0.21	0.06	1.62	27.2	17.1
Change in gait speed		1.45	0.61	0.03	1.38	20.8	1.63	0,54	0.03	1.57	30.2	13.4
Number of steps		22.3	0.66	0.12	21.97	28.0	19.1	0.62	0.02	18.79	32.3	14.6
Step time (s)		0.22	0.14	0.06	0.19	31.2	0.19	0.11	0.04	0.17	27.4	15.7
Gait and pivot turn		18.3	2.33	0.21	18.08	25.2	15.88	2.05	0.11	15.67	28.1	14.6
Total score		14.2	1.23	0.07	13.51	25.6	16.76	1.51	0.42	15.52	25.7	19.6
CM in the frontal plane (mm)	open eyes	3.41	0.37	0.07	3.36	26.9	3.11	0.29	0.08	3.07	28.4	11.8
	closed eyes	3.98	0.33	0.09	3.95	28.1	3.59	0.52	0.48	3.56	30.2	14.7
CM in the sagittal plane (mm)	open eyes	3.04	0.39	0.08	3.16	29.2	2.65	0.24	0.12	2.68	24.9	14.1
	closed eyes	4.02	0.21	0.15	3.98	27.4	3.38	0.43	0.06	3.45	25.4	18.2
Area of an ellipse, (mm^2)	open eyes	95.1	3.31	0.23	93.92	26.2	86.05	3.01	0.21	85.88	29.1	11.2
	closed eyes	175.0	3.99	0.32	174.2	28.6	155.3	4.01	0.35	154.3	31.3	12.3
CBD, %,	open eyes	61.0	5.1	0.45	58.2	30.1	68.2	3.9	0.31	66.1	28.3	12.2
	closed eyes	49.7	3.99	0.28	46.9	29.3	57.3	5.2	0.22	56.3	30.3	15.7

*The differences in the results at the beginning and after of the experiment are significant ($p<0.05–0.001$)

gram provides for the correction of its implementation plan to use special exercises to eliminate vestibular dysfunction, focused on individual symptoms (Sawyer et al, 2016).

The program is distinguished by the developed sets of exercises for self-performance, which were selected based on recommendations for rehabilitation effects on the state of vestibular coordination (Brown et al, 2006) and control of this process (MacKinnon, 2018). The developed program of vestibular rehabilitation is aimed at eliminating the problem with balance by stimulating the organs of vestibular coordination and activating the plasticity of the vestibular system of students after blast TBI.

It is important that during the application of the program when evaluating the test results, we tried to find out which walking parameters showed an impact on the state of the students' vestibular system. The choice of evaluation criteria was guided by the fact that the time index of gait speed is a reliable indicator of control of the rehabilitation process in the case of SCI (Hirsch et al, 2004), and is also used as a predictor of reducing the symptoms of balance disorders to obtain potentially significant indicators of clinical benefit (Schmid et al, 2007). Adjustments to the program content were made based on the results of the initial control to maximize the benefits of the tools used.

The results of testing (Tab. 1) the students of the study sample before the start of classes showed significant deviations in the state of the studied parameters. According to the evaluation of the control data, the studied indicators did not reach the «average» level. Therefore, the data obtained indicate the impact of blast TBI on the state of dynamic balance and gait parameters. At the end of the experiment, the data obtained, despite a significant improvement (+19.6 %), have not yet reached safe values.

In the second stage of control, the students of the study sample demonstrated an improvement in the parameters of balance and gait with obstacles and in difficult conditions. The test results showed a difference in the studied parameters in response to the implementation of the proposed innovations. Statistically significant improvement was observed in determining progress and efficiency A significant improvement in the speed of movement to reach the endpoint was recorded both in walking in a straight line and in difficult conditions.

Even though the descriptive statistical analysis of the stabilometry parameters did not show a complete restoration to normal or average values of the studied parameters after the experiment, it showed a relative stabilization of the upright posture, the destabilization of which in the sagittal and vertical planes was observed at the initial testing. The area of the ellipse, which is considered an indicator of balance control deficit, also showed pathological abnormalities at the beginning of the training, which is typical for people with TBI. A significant role of visual control in the testing process was observed, which is recognized as an important factor in the regulation of balance.

Discussion

Following modern narratives, higher education should be inclusive for all students, including students from vulnerable categories. In implementing the empirical study, we were guided by the fact that inclusive education in the context of

physical education involves the creation of programs that take into account different levels of ability and needs of each participant in the educational process (Telius et al., 2024).

Our study expands the scientific evidence on the need for specialized PE programs (Blavt, & Herasymenko, 2024; Blavt, & Gurtova, 2024), the implementation of which ensures the restoration of damaged body functions of students after blast TBI (Pérez-Rodríguez et al, 2021).

It has been confirmed (Schmid et al, 2007; Hao et al, 2024; Thorman et al., 2022), that an increase in gait speed is an indicator of improvement in the functional state of the body and overall quality of life (Tasseel-Ponche et al, 2023; Kiliç, Çelikyurt, & Algun, 2023). Accordingly, data (Howell, Osternig, & Chou, 2015; Jain et al, 2023) on the impact of VE on balance and gait have been proven (Howell, Osternig, & Chou, 2015; Jain et al, 2023).

The information (Girardi, & Konrad, 1998; Tefertiller et al, 2019; Vander Vegt et al, 2022) on the feasibility of using vestibular rehabilitation tools, which is recognized (Thorman et al, 2022; Badke et al, 2004; Kiliç, Çelikyurt, & Algun, 2023) as a highly effective method of eliminating functional disorders of the vestibular system and balance system, has been expanded. Our study is consistent with the information (Alsalaheen et al, 2010; Valovich McLeod, & Hale, 2015; Aligene & Lin, 2013) that vestibular rehabilitation provides improvement in gait and balance functions after BI.

The present study was the first to use DGI to monitor the dynamic balance of students after blast TBI, implemented in the framework of inclusive physical education. The obtained results expand the information of previous studies on the feasibility of using the control of gait and balance parameters in the rehabilitation process after blast TBI (Bland, Zampieri, & Damiano, 2011; Alashram et al, 2020; Joyce et al, 2022). And information about the possibility of correcting lost functions after TBI among university students (Smetana et al, 2024), and the need to take into account additional complexities in blast TBI.

We support the scientific approaches (Dever et al, 2022; Fino et al, 2018) regarding the need for further research to create a gait assessment procedure to fully determine gait disorders after TBI.

Conclusions

The high proportion of people with blast TBI during the war in Ukraine has become a significant problem among both military and civilians who become students of higher education institutions every year. The restoration of lost body functions due to blast TBI in students within an educational institution is realized in the process of inclusive PE.

The need for a comprehensive study of the issue of inclusion in physical education in higher education is due to the contradictions between the need for a large-scale restructuring of the national system, modernization of its components, development, and implementation of practical performance of the educational process of students who received blast TBI as a result of war and the lack of such experience in terms of inclusion in line with the challenges of the time.

The developed program of inclusive PE after blast TBI is presented. The content of the program is aimed at providing maximum opportunities for differentiation of the educational process and implementation of an individual approach in its implementation. The results of the test control showed the effectiveness of the implemented innovations in the range of 10-19.5 %. A significant improvement in the studied parameters of balance and gait was found. The conducted research on the final assessment of DGI and the coefficient of balance development allows us to state the effectiveness of the implemented program of physical rehabilitation of students after blast TBI in the process of inclusive PE.

For the first time, we have implemented a study of students after blast TBI, in which we directly controlled the violation of dynamic balance and gait in inclusive PE. The results obtained are evidence that strategies and approaches will be effective, efficient and lead to the desired result in the case of improving practical methods to develop a reliable evidence base. The latter should be the basis for the formation of an appropriate practical basis for the implementation of inclusive physical education, the development of rehabilitation tools. Meanwhile, there is an obvious need for deeper, large-scale studies of blast TBI among students, as the choice of rehabilitation methods remains an open question.

Conflicts of Interest

No conflicts of interest exist.

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Відновлення втрачених функцій у здобувачів вищої освіти після вибухової черепно-мозкової травми в процесі інклюзивного фізичного виховання

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Реферат. Стаття: 8 с., 1 табл., 63 джерела.

Визначено, що нині основними завданнями вищої освіти в є розв'язання проблеми надання студентам, які отримали травми внаслідок війни можливостей поряд із здобуттям вищої освіти, умов реабілітації.

Мета статті – виявити ефективність впливу розробленої програми інклюзивного фізичного виховання на відновлення функцій динамічної рівноваги у здобувачів вищої освіти після вибухової черепно-мозкової травми.

Матеріали та методи. У дослідженні комбіновано застосовані теоретичні (аналіз, синтез, узагальнення) й емпіричні методи (педагогічний експеримент, тестування). Тестування реалізовано з використанням вправи «Індекс динамічної ходи» та методу стабіліографії. До експерименту, який реалізовано протягом навчального року у академічному курсі фізичного виховання, залучено 30 здобувачів вищої освіти чоловічої статі після вибухової черепно-мозкової травми, за умови відсутності ускладнень.

Результати. Представлено розроблену програму інклюзивному фізичному вихованні після вибухової черепно-мозкової травми. Зміст програми скерований на забезпечення максимальних можливостей диференціації освітнього процесу та здійснення індивідуального підходу у його реалізації. Підсумками тестового контролю здобувачів вищої освіти досліджуваної вибірки до початку занять засвідчено про значних відхилень у стані досліджуваних параметрів. Згідно оцінюванню отриманих даних контролю, досліджувані показники не досягали рівня «середній», що є наслідком впливу вибухової черепно-мозкової травми на стан динамічної рівноваги та параметри ходи. Прикінцеве тестування засвідчило різницю досліджуваних параметрів у відповідь на упровадження запропонованих новацій. Статистично значуще покращення спостерігалося у визначення прогресу та ефективності досліджуваних параметрів ходи та рівноваги у межах 10-19.6 %.

Висновки. Нами вперше реалізовано дослідження щодо здобувачів вищої освіти після вибухової черепно-мозкової травми, у якому безпосередньо контролювали порушення динамічної рівноваги та ходи у інклюзивному фізичному вихованні. Отримані результати є свідченням того, що стратегії та підходи будуть ефективними, результативними та такими, що призводять до бажаного результату у разі вдосконалення практичних методик задля розробки надійної доказової бази.

Ключові слова: інклюзія, фізичне виховання, здобувач вищої освіти, рівновага, хода, вибухова черепно-мозкова травма.

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