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Original Scientific Article

Gamified Inclusive Physical Education as an Adaptive Rehabilitation Model for University Students with Blast Traumatic Brain Injury

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Abstract

Background. The ongoing war in Ukraine has increased the number of university students living with disabilities caused by blast traumatic brain injury (TBI). This situation creates an urgent need for inclusive physical education models that combine rehabilitation goals with effective motivational strategies. Gamification may enhance participation, adherence, and functional recovery within adaptive learning environments.

Objectives. The purpose of this study was to determine the effectiveness of a gamified inclusive physical education program as an adaptive rehabilitation model for university students with blast traumatic brain injury.

Materials and Methods. Twenty-eight first-year male students aged 18–23 years with mild blast TBI and mild functional impairment participated in the study. Participants were divided into a control group (n = 14) and an experimental group (n = 14). The control group followed a standard inclusive physical education program, while the experimental group completed a vestibular rehabilitation program integrated with gamification elements. The intervention lasted two academic semesters. Functional changes were assessed using the Lower Quarter Y-Balance Test and the Figure-of-8 Walk Test. Data were processed using descriptive statistics and Student's t-test.

Results. At baseline, no statistically significant differences were observed between groups ($p > .05$). After the intervention, the experimental group demonstrated substantially greater improvements than the control group across all indicators. Gains in the experimental group ranged from 15.3% to 22.1%, while changes in the control group did not exceed 5.7%. The largest effects were observed in walking efficiency, balance control, and coordination performance.

Conclusions. Gamified inclusive physical education can be considered an effective adaptive rehabilitation model for university students with blast traumatic brain injury. The integration of structured physical exercises with motivational game mechanics improved functional outcomes, engagement, and movement confidence. The findings support the use of gamification in inclusive university physical education under conditions of increased rehabilitation demand.

Keywords: inclusive physical education, gamification, traumatic brain injury, adaptive learning, rehabilitation, university students, balance, coordination.

Introduction

The full-scale war in Ukraine has created new challenges for higher education institutions, including a growing number of students living with disabilities caused by combat actions and missile attacks (Klos, Blavt, & Kovalchuk, 2024). Among these conditions, blast traumatic brain injury (TBI) has become one of the most significant because of its complex neurological, vestibular, and functional consequences. Common post-injury manifestations include impaired balance, dizziness, gait instability, reduced coordination, and decreased confidence in movement performance (Dang et al., 2017; Row et al., 2019; Fulk et al., 2024). These limitations may substantially reduce students' participation in academic and social life and require new inclusive support strategies.

In this context, inclusive physical education should be considered not only as a curricular discipline, but also as an adaptive educational environment capable of supporting rehabilitation, functional recovery, and social reintegration. Previous studies have shown that physical education possesses considerable rehabilitative potential because structured movement tasks may improve postural control, restore coordination patterns, and increase functional independence in persons with disabilities (Pellerin, Wilson, & Haegele, 2022; Lieberman, Houston-Wilson, & Grenier, 2024; Blavt, & Herasymenko, 2024).

However, conventional rehabilitation-oriented exercise programs often face a persistent problem of low adherence

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caused by monotony, anxiety, and insufficient motivational support. This challenge becomes particularly relevant in university students who must sustain long-term participation while simultaneously adapting to academic demands. Therefore, the search for instructional approaches that combine therapeutic value with stable motivation remains important.

One promising solution is gamification. Gamification refers to the use of game mechanics such as points, levels, challenges, rewards, and immediate feedback in non-game contexts. In educational settings, gamification has been associated with higher motivation, stronger task engagement, and improved persistence in learning activities (Ferriz-Valero et al., 2020; Fernandez-Rio et al., 2020; Arufe-Giráldez et al., 2022). In physical education, gamification may transform repetitive rehabilitation exercises into meaningful and goal-directed activity while maintaining learner interest (Hsia et al., 2025; Jadán-Guerrero et al., 2023).

From the perspective of learning theory, gamified rehabilitation may be interpreted as an adaptive learning model in which physical tasks are progressively adjusted according to learner performance and current functional state. This creates a dynamic cycle of action, feedback, correction, and achievement. Such an approach appears especially relevant for students with blast TBI, whose recovery requires gradual progression, individualized pacing, and sustained motivation.

Despite growing interest in inclusive education and digital motivational strategies, studies examining gamified physical education programs specifically for university students with blast traumatic brain injury remain limited (Sotos-Martínez et al., 2024; Youness, Ouhrir, & Lotfi, 2026). This creates both scientific and practical need to evaluate effective intervention models for this population.

The purpose of this study was to determine the effectiveness of a gamified inclusive physical education program as an adaptive rehabilitation model for university students with blast traumatic brain injury.

Material and methods

Research methods

The study was designed using an integrated methodological approach that combined theoretical analysis with empirical intervention testing. The research included two interconnected stages: conceptual development and experimental verification: theoretical and empirical.

At the theoretical stage, relevant literature on inclusive physical education, rehabilitation after traumatic brain injury, and gamification in educational settings was reviewed to develop the conceptual framework of the intervention.

The empirical stage involved evaluation of the proposed program through a controlled educational intervention. Participants were informed about the aims and procedures of the study before enrollment and provided voluntary consent to participate correctness of the pedagogical process.

Functional tests were selected according to feasibility, low equipment requirements, short administration time, and established practical relevance. Based on these criteria, the Lower Quarter Y-Balance Test (LQYBT) and the Figure-of-8 Walk Test (F8W) were used. The F8W was selected as an ecologically valid measure of walking performance involving both linear and curved movement trajectories (Triolo et al., 2025).

The test procedure. The LQYBT has the student stand on one leg while reaching out in 3 different directions with the other lower extremity (Fig. 1). They are anterior, posteromedial and posterolateral The maximal reach is measured by reading the distance at the edge of the reach indicator closest to the subject to the nearest half centimeter. The limb being tested is the stance limb (Physiopedia: Y Balance Test). The total indicator (composite) was determined by the value of the three directions.

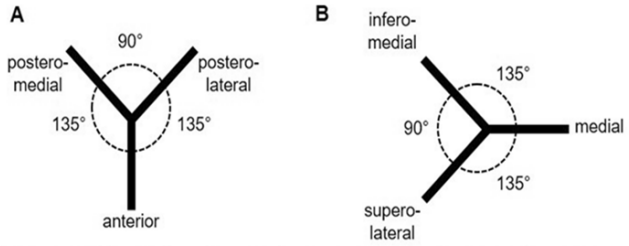

Fig. 1. Scheme of the LQYBT (Schwiertz, Beurskens, & Muehlbauer, 2020)

The F8WT uses a path where the participant is asked to walk a figure of eight shape around two cones (Fig. 2.). Scores are recorded in three areas: speed (time for completion), number of steps taken and pace (Physiopedia: Figure of 8 Walk Test).

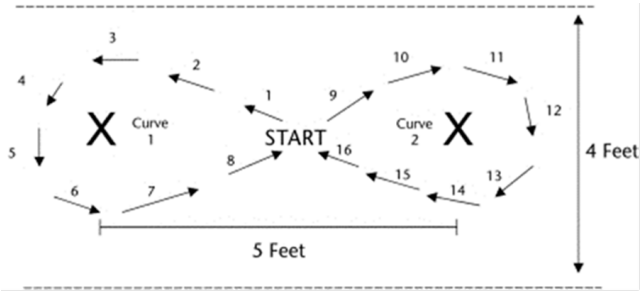

Fig. 2. Scheme of the Figure-of-8 Walk (Hess et al., 2010)

The platform «Fitocracy» was an online game and social network that aims to use gamification to help users improve their fitness (Adrianne, 2011).

Study participants

Participants were twenty-eight first-year male university students aged 18 to 23 years with mild blast traumatic brain injury and mild functional impairment. The participants were recruited from Lviv Polytechnic National University and Kamianets-Podilskyi National Ivan Ohiienko University.

All participants were informed about the study procedures and provided written voluntary consent prior to participation. Inclusion criteria included mild blast traumatic brain injury without severe comorbid pathological conditions.

Medical clearance for participation in physical activity was confirmed for all participants prior to the intervention.

The study was conducted in accordance with the ethical principles of the Declaration of Helsinki and relevant international standards for research involving human participants.

Research organization

To implement the study, a total of twenty-eight students were allocated into two groups: control group (CG, n = 14) and experimental group (EG, n = 14). The independent variable was the content and structure of the inclusive physical education program. The control group followed the standard inclusive physical education curriculum. The experimental group participated in a vestibular rehabilitation program integrated with gamification elements.

Based on the results of the test control of the students of the studied sample who completed the course in full, the conclusions of the study were substantiated. The testing procedure did not differ from the generally accepted one, the tests were performed in the gym. Outcome assessments were conducted at baseline (September) and after completion of the intervention (May). The intervention lasted two academic semesters. All tests were administered under standardized gymnasium conditions.

Statistical analysis

Quantitative data were analyzed using SPSS Version 21. Descriptive statistics included means, standard errors, standard deviations, minimum and maximum values, and coefficients of variation. Distribution normality was examined using the Shapiro-Wilk test. Between-group baseline comparisons were performed using Student's t-test. Statistical significance was set at $p < .05$.

Results

When forming the key provisions of the inclusive PE program, we were primarily guided by the fact that the key goals in blast TBI are to improve balance and coordination (Eapen, & Cifu, 2018). The developed program is based on vestibular rehabilitation with elements of gamification. Therefore, the classical principles of vestibular rehabilitation were combined with motivational game mechanics: points, levels, challenges, and feedback.

Vestibular rehabilitation consists of repeated performance of certain actions or movements that cause mild dizziness or instability (Tan, & Stern, 2026). This regular training can allow the brain and body to adapt to a chronic problem of dizziness or recover from an acute vestibular injury.

Gamification in education is understood as the introduction of games, game techniques and game practices for educational purposes. A distinctive feature of gamification is that one exercise works at several levels at once: motor, neural and behavioral (Fernandez-Rio et al., 2020). In fact, this combination provides a rapid and stable impact.

The main application of gamification is to increase the effectiveness of the educational process. This approach turns learning into an exciting process, offering immediate feedback and a sense of success.

The goal of the inclusive PE program for students with disabilities due to blast TBI is defined as: restoring balance function, reducing dizziness, improving coordination and stability, and increasing motivation through the game process.

When selecting the means of implementing the program, it was taken into account that blast TBI often gives a combination of vestibular, cognitive and sensory disorders. Therefore, special attention was paid not only to the content of vestibular rehabilitation tools but also to the control of load and fatigue.

The content of the program used short complexes of simple exercises: vestibular gymnastics, balance exercises, coordination exercises, including with objects, and proprioceptive exercises. The duration of the complexes is 5–15 min with pauses. At the same time, sensory overload from the effects of light, sound, and movement was minimized. Individualization of the load was implemented depending on the symptoms. They gradually moved from static exercises to dynamic and complex coordination tasks.

Gamification was subordinated to the goals of vestibular rehabilitation. In the case when the game overloaded or provoked symptoms, it was simplified or removed. The so-called «calm rehabilitation game» was used at a calm pace without elements of bright gamification. Flickering, loud sounds, and overloaded interfaces were avoided.

The app used "Fitocracy", has a large amount of content, such as workout guides, nutrition tips, etc. It provides the opportunity for students to form groups and compete with each other.

New, more complex exercises became available only after successfully completing the basic level. The level of complexity was gradually increased, new exercises were discovered, and sensory load was increased based on test control data. Effective gamification in rehabilitation is: maximum therapeutic benefit, minimum sensory overload and stable motivation.

The effectiveness of the developed program was tested by implementing the second part of the experimental study. Given that an objective and unified assessment of the functional state of the body is an essential component of rehabilitation measures. Test control was used as the basis for personalized corrections of the means of influence.

At the initial stage of the study, a comparative analysis of indicators in the EG and CG was conducted (Table 1). The absence of statistically significant differences between the groups was established, which is confirmed by the Student's t-test values of $p>0.05$. At the end – the result was completely different.

Preliminary analysis using the Shapiro-Wilk W-test indicated that the distributions of the studied variables did not substantially deviate from normality ($W = 0.79–0.95$). Therefore, parametric procedures were considered appropriate. Baseline comparisons using Student's t-test revealed no statistically significant differences between the experimental and control groups ($p > .05$), indicating initial comparability of the groups.

Post-intervention analysis demonstrated positive changes across all measured indicators in both groups; however, improvements were substantially greater in the experimental group (Table 2) than in the control group (Table 3). Mean relative gains in the experimental group ranged from 15.3% to 22.1%, whereas corresponding changes in the control group did not exceed 5.7%. Variability in the experimental group also decreased after the intervention, as reflected by lower coefficients of variation, suggesting more stable performance in balance and coordination tasks in EG participants.

Table 1. Test results before the start of the experiment (n = 28)

Component indicator		Basic statistics							
		X	m	S	Min	Max	V	D	p
Anterior	CG	55.01	0.53	6.22	41.88	65.14	14.55	0.923	0.005432
	EG	58.41	0.31	6.18	40.01	66.02	14.99	0.929	0.005421
Posteromedial	CG	83.01	1.65	5.13	65.11	88.29	13.91	0.888	0.003301
	EG	86.32	1.11	6.13	74.16	95.2	8.03	0.932	0.007201
Posterolateral	CG	81.6	1.51	6.15	68.06	95.14	8.03	0.926	0.005321
	EG	80.2	0.95	5.12	64.18	90.44	6.38	0.864	0.002109
Composite	CG	219.08	7.89	15.08	164.0	231.03	23.3	0.793	0.005641
	EG	224.93	8.57	14.84	248.15	210.2	19.79	0.815	0.004391
F8W Time (sec)	CG	9.34	0.223	1.94	7.94	11.74	12.81	0.936	0.006132
	EG	9.11	0.76	0.14	7.55	11.62	8.33	0.942	0.005221
F8W Steps (number)	CG	15.18	0.28	1.52	10.62	19.03	10.01	0.882	0.001534
	EG	14.88	0.26	1.49	12.02	16.12	11.13	0.956	0.000168
F8W Rate (number /sec)	CG	1.85	0.051	0.16	1.71	1.98	10.22	0.914	0.000134
	EG	1.93	0.07	0.19	1.82	2.03	12.01	0.872	0.000391

Table 2. Results of test control at the end of the experimental study EG (n = 14)

Statistical parameters gait	Test tasks and measurement results								
	at the beginning of the experiment				after of the experiment				
	X	m	S	V	X	m	S	V	effect%
Anterior	58.4	0.31	6.18	14.99	67.33	0.29	5.15	6.1	15.3
Posteromedial	86.32	1.11	6.13	8.03	102.81	1.03	5.71	8.3	19.1
Posterolateral	80.2	0.95	5.12	6.38	94.07	0.91	5.22	6.5	17.3
Composite	224.93	8.57	14.84	19.79	265.19	7.22	13.14	8.2	17.9
F8W Time (sec)	9.1	0.76	0,14	8.33	7.30	0.61	0.46	7.9	19.8
F8W Steps (number)	14.99	0.26	1.49	11.13	11.68	0.21	1.43	7.3	22.1
F8W Rate (number /sec)	1.93	0.07	0.19	12.01	2.34	0.06	0.22	3.8	21.3

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

Table 3. Results of test control at the end of the experimental study CG (n = 14)

Statistical parameters gait	Test tasks and measurement results								
	at the beginning of the experiment				after of the experiment				
	X	m	S	V	X	m	S	V	effect%
Anterior	55.01	0.53	6.22	14.55	57.05	0.31	6.01	10.3	3.7
Posteromedial	83.01	1.65	5.13	13.91	87.33	0.17	1.71	12.1	5.2
Posterolateral	81.6	1.51	6.15	8.03	85.07	1.31	6.28	9.9	5.1
Composite	219.08	7.89	15.08	23.3	229.81	8.03	14.44	13.4	4.9
F8W Time (sec)	9.34	0.223	1.94	12.81	8.81	0.33	1.66	12.6	5.7
F8W Steps (number)	15.18	0.28	1.52	19.03	14.50	0.31	1.53	13.4	4.5
F8W Rate (number /sec)	1.85	0.51	0.16	10.22	1.94	0.65	0.21	12.6	4.9

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

Reductions in standard errors and standard deviations after the intervention suggest a more consistent level of functional performance among participants in the experimental group. Marked improvements in Figure-of-8 Walk outcomes may reflect enhanced movement efficiency, dynamic control, and task confidence developed during the program improve vestibular response.

The largest improvement was observed in the posteromedial reach direction (19.1%), which may indicate better proprioceptive regulation and lower-limb stabilization capacity. In addition, faster completion time (19.8%) and fewer steps (22.1%) in the Figure-of-8 Walk Test suggest more efficient gait organization and improved locomotor control with optimal step length.

Although the control group also demonstrated modest positive changes, the magnitude of improvement was consistently smaller than that observed in the experimental group across all indicators.

Discussion

The findings indicate that the gamified inclusive physical education program was more effective than the standard format in improving balance, coordination, and walking performance in university students with blast traumatic brain injury. These results support the view that physical education may function not only as an academic discipline, but also as a structured rehabilitation environment for students with disability-related functional limitations.

The observed improvements in dynamic balance suggest positive changes in postural control, vestibular adaptation, and proprioceptive regulation. Balance impairment is one of the most common persistent consequences of traumatic brain injury and substantially affects functional independence, confidence in movement, and participation in daily activities (Dang et al., 2017; Row et al., 2019; Fulk et al., 2024). Previous studies have shown that structured movement programs may improve stability and restore impaired motor patterns in persons with disabilities (Pellerin, Wilson, & Haegele, 2022; Lieberman, Houston-Wilson, & Grenier, 2024). The present results extend these findings to the context of university students with blast traumatic brain injury.

Marked positive changes in walking efficiency and coordination may be explained by the progressive and task-oriented character of the intervention. Repeated practice with gradual increases in difficulty is considered one of the key mechanisms of motor recovery after neurological impairment. Continuous correction during movement execution also contributes to sensorimotor relearning and more stable movement control (Blavt & Herasymenko, 2024). These principles were incorporated into the design of the experimental program and may explain its superiority over the standard format.

An additional explanation for the observed effects may be the motivational influence of gamification. Previous research has associated gamified learning environments with higher engagement, stronger persistence, and more positive attitudes toward regular participation (Ferriz-Valero et al., 2020; Fernandez-Rio et al., 2020; Arufe-Giráldez et al., 2022). In physical education, game mechanics such as progression levels, challenges, rewards, and immediate feedback may transform repetitive rehabilitation tasks into meaningful goal-directed activity (Hsia et al., 2025; Jadán-Guerrero et al., 2023). This mechanism may be particularly important for students recovering from blast traumatic brain injury, for whom monotony, anxiety, and reduced confidence may limit adherence.

The results may also indicate broader psychoeducational benefits of the program. Increased confidence in movement performance, successful task completion, and visible progress may positively influence self-efficacy and readiness for participation in academic and social life. Although these variables were not directly measured, such effects are theoretically consistent with adaptive learning models based on feedback, progressive challenge, and achievable goals.

Another important implication concerns the role of personalization. Recovery after traumatic brain injury often requires individual pacing, continuous monitoring, and adjustment of task difficulty according to current functional capacity. Gamified systems are well suited to this requirement because they allow flexible progression and immediate response to learner performance. Therefore, gamification in this context should be considered not merely a motivational addition, but also a practical tool for individualized rehabilitation management.

The study also contributes to the still limited evidence base concerning gamified rehabilitation approaches for persons with traumatic brain injury. Previous authors have emphasized the need for innovative strategies that reduce monotony and improve adherence during recovery processes (Välimäki et al., 2017; Sgubin, Deodato, & Murena, 2023). The present findings suggest that inclusive university physical education may provide an effective setting for implementing such strategies.

The practical relevance of the results is especially high for contemporary Ukrainian higher education. Under wartime conditions, universities increasingly face the need to support students whose disabilities are associated with blast injuries. Therefore, inclusive physical education should move beyond formal participation models and incorporate evidence-based rehabilitation approaches integrated into the educational environment. The tested program represents one feasible model combining inclusion, functional recovery, and sustained participation.

The control group also demonstrated modest positive changes, which may reflect the general benefits of regular physical activity. However, the substantially smaller magnitude of improvement indicates that standard physical education formats alone may be insufficient for students with blast traumatic brain injury who require targeted and adaptive support.

Limitations

This study has several limitations. The sample size was relatively small and included only male first-year students, which limits the generalizability of the findings. The intervention was conducted in two universities only, and institutional differences were not separately analyzed. Long-term retention of functional gains after completion of the program was not examined. In addition, psychological outcomes such as motivation, anxiety, self-efficacy, and quality of life were not directly measured. Future studies should include more diverse samples, broader institutional settings, psychological indicators, and follow-up assessments after program completion.

Conclusions

The gamified inclusive physical education program showed superior outcomes compared with the standard format in improving balance, coordination, and walking performance in university students with blast traumatic brain injury. Functional gains in the experimental group substantially exceeded those observed in the control group, indicating the added value of a structured intervention combining rehabilitation tasks with motivational game mechanics.

The integration of vestibular rehabilitation exercises with progression-based challenges and immediate feedback likely enhanced participant engagement, adherence, and confidence in movement performance. These findings support the interpretation of post-injury recovery within physical education as an adaptive learning process based on repeated practice, performance feedback, and gradual task progression.

The practical relevance of the study is especially high for contemporary Ukrainian higher education, where wartime

conditions have increased the need to support students with disability related to blast injuries. In this context, inclusive physical education should extend beyond formal participation models and incorporate evidence-based strategies that combine educational inclusion with functional rehabilitation.

The results suggest that gamified inclusive physical education may serve as a feasible university-based model for addressing balance and coordination limitations in students with blast traumatic brain injury. Future research should examine long-term effects, psychological outcomes, and the applicability of this approach across broader student populations and institutional settings.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

AI Transparency Statement

The author declares that no generative AI or AI-assisted technologies were used in the writing, editing, or preparation of this manuscript.

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Clarified Ethics Approval

This study was approved by the Research Ethics Committee Міжнародного Kamianets-Podilskyi National Ivan Ohiienko University (KPNU 2025-014) before the start of the study.

Conflicts of interest

No conflicts of interest exist.

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Гейміфіковане інклюзивне фізичне виховання як адаптивна реабілітаційна модель для студентів закладів вищої освіти з вибуховою черепно-мозковою травмою

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

Реферат. Стаття: 12 с., 3 табл., 2 рис., 21 джерело.

Актуальність. Триваюча війна в Україні призвела до зростання кількості студентів закладів вищої освіти, які мають інвалідність, спричинену вибуховою черепно-мозковою травмою (ЧМТ). Ця ситуація зумовлює нагальну потребу в моделях інклюзивного фізичного виховання, що поєднують реабілітаційні завдання з ефективними мотиваційними стратегіями. Гейміфікація може сприяти підвищенню участі, прихильності до занять та функціональному відновленню в умовах адаптивного освітнього середовища.

Мета дослідження. Визначити ефективність програми гейміфікованого інклюзивного фізичного виховання як адаптивної реабілітаційної моделі для студентів закладів вищої освіти з вибуховою черепно-мозковою травмою.

Матеріали і методи. У дослідженні взяли участь 28 студентів першого курсу чоловічої статі віком 18–23 років із легкою вибуховою ЧМТ та помірними функціональними порушеннями. Учасників було розподілено на контрольну групу (n = 14) та експериментальну групу (n = 14). Контрольна група навчалася за стандартною програмою інклюзивного фізичного виховання, тоді як експериментальна група виконувала програму вестибулярної реабілітації, інтегровану з елементами гейміфікації. Тривалість втручання становила два академічні семестри. Функціональні зміни оцінювали за допомогою тесту Lower Quarter Y-Balance Test та тесту Figure-of-8 Walk Test. Дані опрацьовували методами описової статистики та t-критерію Стьюдента.

Результати. На початковому етапі статистично значущих відмінностей між групами не виявлено ($p > .05$). Після завершення втручання експериментальна група продемонструвала суттєво вищі покращення порівняно з контрольною групою за всіма показниками. Приріст результатів в експериментальній групі становив від 15,3% до 22,1%, тоді як зміни в контрольній групі не перевищували 5,7%. Найбільші ефекти зафіксовано щодо ефективності ходьби, контролю рівноваги та координаційних здібностей.

Висновки. Гейміфіковане інклюзивне фізичне виховання може розглядатися як ефективна адаптивна реабілітаційна модель для студентів закладів вищої освіти з вибуховою черепно-мозковою травмою. Інтеграція структурованих фізичних вправ із мотиваційними ігровими механіками сприяла покращенню функціональних показників, залученості до занять і впевненості у руховій діяльності. Отримані результати підтверджують доцільність використання гейміфікації в інклюзивному фізичному вихованні закладів вищої освіти в умовах зростання потреб у реабілітації.

Ключові слова: інклюзивне фізичне виховання, гейміфікація, черепно-мозкова травма, адаптивне навчання, реабілітація, студенти закладів вищої освіти, рівновага, координація.

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