Physical Education Theory and Methodology
Теорія та методика фізичного виховання

ISSN 1993-7989 (print)
ISSN 1993-7997 (online)
ISSN-L 1993-7989

Original Scientific Article

An Analytical Programmed Tool for Improving the Reliability of the Figure-of-8 Walk Test in Inclusive Physical Education

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

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Accepted for Publication: November 27, 2025
Published: November 30, 2025

DOI: 10.17309/tmfv.2025.6.13

Abstract

Objectives. The purpose of the study was to determine the reliability of the Figure-of-8 Walk Test in inclusive physical education using a newly developed analytical programmed tool.

Materials and Methods. The study was conducted at both theoretical and empirical levels. A pedagogical experiment was carried out using the Figure-of-8 Walk Test (F8W). The sample consisted of first-year university students who had sustained war-related injuries, including blast-induced traumatic brain injury (TBI) and blast TBI combined with acoustic trauma.

Results. The findings of the study are implemented in the newly developed analytical programmed tool designed to support the execution of the F8W. Its core component is a wireless autonomous data collection system that integrates an inertial measurement unit (IMU), a sensor system supported by a neural network, a processing unit, and a Portenta H7 controller—providing a combination of technological integration and artificial intelligence.

The IMU was attached to the participant's body during the execution of the F8W. In real time, measurements of acceleration, velocity, and position were transmitted via Bluetooth. As the participant moved along the test course, the sensor system – supported by the neural network and processing unit – recorded detailed movement data and transmitted it to the microcontroller platform. The Portenta H7 platform aggregated the test parameters from the IMU and sensor system with flexible activation and data-buffering capabilities.

The wireless autonomous data collection system processed the output control data while the participant performed the F8W and displayed the information on a PC interface. Statistical verification of the obtained data confirmed that the analytical programmed tool ensures high reliability and validity of F8W measurements. In contrast, traditional recording methods demonstrated low reliability and validity, primarily due to the influence of the human factor.

Conclusions. The study demonstrated that the developed analytical tool for real-time assessment of mobility parameters in students with war-related injuries provides excellent measurement reliability compared to conventional Figure-of-8 Walk Test procedures. The tool offers substantial advantages over traditional methods of manual data recording, enhancing accuracy, objectivity, and reproducibility of F8W performance evaluation.

Keywords: student, war injuries, physical education, inclusion, control, testing, Figure of 8 Walk Test.

Introduction

In a situation of active combat operations on the territory of Ukraine for more than 10 years in a row and the amount of artillery weapons currently in use, which is unprecedented in the history of wars, there is almost no chance for soldiers to avoid injury. However, being in the rear does not protect against war injuries. Along with a large number of military personnel, a significant number of civilians are exposed to shock waves affecting the brain as a result of daily shelling. Most often, the shock wave causes a concussion (Latin: commotio, English: concussion, or equivalent name – mild Traumatic Brain Injury (mTBI) (Romeu-Mejia, Giza & Goldman, 2019), which may be accompanied by complications – blast TBI with acoustic trauma (Weppner, Linsenmeyer & Ide, 2019; Phipps et al., 2020). Such injuries may lead to long-term consequences and significantly complicate life (Denby et al., 2020; Haarbauer-Krupa et al., 2021; Sepehry, Schultz & Mallinson, 2024; Leland et al., 2016).

The war has forced the professional community of higher education institutions to pay additional attention to this problem. In higher education, inclusive physical education helps restore students' impaired functions (Pellerin, Wilson & Haegele, 2022; Lieberman, Houston-Wilson & Grenier, 2024).

In this regard, it should be noted that the level of physical activity is determined by factors that influence the quality of life related to health after injuries (Brittain & Green, 2012; Galeno et al., 2022; Lorenz et al., 2018). Conversely, a lack of physical activity, as claimed (Shirazipour, Aiken & Latimer-Cheung, 2017; Rosa et al., 2025; Jamieson & Wijesundara 2025), poses a significant problem for the health of injured individuals.

Given the above arguments, we position the quality of inclusive physical education in higher education as a factor in effectively overcoming the physical consequences of students' lost functions due to injuries in order to improve their condition, mobility, and quality of life.

Analysis of recent research and publications. Scientists claim that balance and mobility disorders are the most common disorders after mTBI (Alashram, Padua & Annino, 2022; Denby et al., 2020); after blast TBI with acoustic trauma (Shvets, Podolian & Holinko, 2020; Haarbauer-Krupa et al., 2021; Blavt & Gurtova, 2024).

Data from numerous scientific sources (Willingham et al., 2024) indicate that physical activity plays a leading role in the recovery of impaired functions. In particular, it improves balance, mobility, and eliminates unsteadiness after mTBI (Bland, Zampieri & Damiano, 2011), after blast TBI with acoustic trauma (Weppner, Linsenmeyer & Ide, 2019; Phipps et al., 2020; Blavt & Gurtova, 2024).

It is argued (Phipps et al., 2020; Wellons et al., 2022) that the consequences of injuries in terms of impaired coordination, balance, mobility, and gait parameters have certain patterns. However, as researched (Vander Vegt et al., 2022; O'Neil et al., 2019; Romeu-Mejia, Giza & Goldman, 2019), the course of these disorders will be individual.

Research has shown that the impact of inclusive physical education on the recovery process requires objective monitoring (Blavt et al., 2023; Maher, van Rossum & Morley, 2023; Kuntjoro et al., 2024). It has been established (Rosa, 2025; Jamieson & Wijesundara 2025; Xu et al., 2024) that such monitoring provides valuable information and feedback, tracks progress, and contributes to the development and evaluation of future programs

It has been proven that due to the numerous complex and diverse impairments associated with trauma (Romeu-Mejia, Giza & Goldman, 2019; Brassel et al., 2021), it is possible to implement such monitoring by applying innovative technologies (de Miguel-Fernández et al., 2023; Koenig et al., 2023; Chaparro-Cárdenas et al., 2019).

As established (Jones, DeRuyter & Morris, 2020; Jantz, P.B., Davies & Bigler, 2014; Santilli et al., 2025), innovative technologies are a factor in the effectiveness of physical education (Zhong et al., 2025; Xu et al., 2024), the process of recovery, prevention of regression, tracking changes, and ensuring a healthy lifestyle.

Scientific works (Bolatuly Omarov, Zhunusbekov & Aliyev, 2025; Chao, Yi, Min & Long, 2024; Zhong et al., 2025) confirm that the quality of physical education in general, and inclusive physical education in particular (Toto et al., 2024; Li, 2025; Adeleye, Eden & Adeniyi, 2024) is currently determined by the quality of control implemented by the latest tools, including artificial intelligence tools (Zhou et al., 2024; Wu et al., 2025; Vasco Delgado et al., 2025).

The purpose of the study is to establish the reliability of the Figure-Of-8 Walk Test in inclusive physical education using the developed analytical programmable tool.

Materials and Methods

Research Methods

To achieve the set goal, the research was carried out in two stages: theoretical and empirical. The theoretical stage involved the collection of scientific information on the specific research topic in the field of inclusive physical education and innovative technological developments in this area of knowledge. To form the theoretical basis of the study, methods of analysis, synthesis, and generalization were used.

The empirical stage involved the implementation of the research idea using design methods to create a digital tool, a pedagogical experiment at the stage of collecting the necessary data using testing, and mathematical analysis of the data obtained.

Testing was carried out using the Figure of 8 Walk Test (F8W). The choice of F8W for our study was due to the suitability of this test for monitoring walking skills in everyday life (Hess et al., 2010). In addition, the F8W is an easy-to-use tool for monitoring the walking skills of people

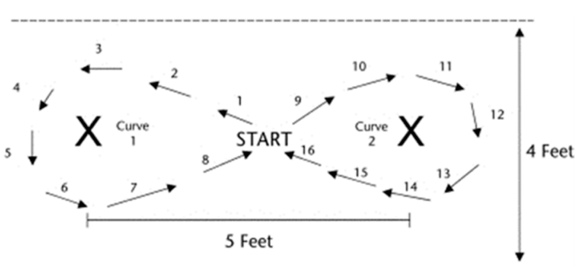

Fig. 1. Scheme of the Figure-of-8 Walk (Hess et al., 2010)

with disabilities, as it correlates with functional mobility, walking speed, and balance (Soke et al., 2023).

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

Study Participants

The study involved 28 male students who had suffered war-related injuries and who had enrolled in the first year of study at y Lviv Polytechnic National University, Lviv State University of Physical Culture named after Ivan Boberskyj, Stepan Gzhytskyi National University of Veterinary Medicine and Biotechnologies of Lviv, Drohobych Ivan Franko State Pedagogical University, Kamianets-Podilskyi National Ivan Ohiienko University, Lutsk National Technical University.

The students' ages ranged from 18 to 23 years. Criteria for inclusion of students in the study: presence of war-related trauma, written consent to participate in the study. Criteria for exclusion of students from the study: refusal to participate in the study; presence of any concomitant diseases, musculoskeletal, neurological, or cardiopulmonary diseases as a result of trauma, or exacerbation of the consequences of trauma.

All participants in the study sample were involved in the experiment on the basis of anonymity and confidentiality. Voluntary written consent to participate in the testing was obtained.

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

Before the experiment, the participants in the study sample were instructed on the testing conditions. After the experiment, the data obtained were reanalyzed and compared, and a final experimental conclusion was made. The experimental process was implemented as part of a university physical education course. The study was a comparative experiment, in which the experimental factor was the method of recording the test results. In the first case, the recording method required instrumental control using a specially developed tool, and in the second case, a stopwatch was used.

The maximum speed was measured twice, and the average time result was used for analysis. To determine the F8W pace, the number of measured F8W steps was divided by the F8W time.

Statistical Analysis

The analysis of the research results involved the use of mathematical statistics methods. The correlation analysis method was used to measure the strength of the relationship based on the determination of the intraclass correlation coefficient (rtt) (Riemann & Lininger, 2018) and the coefficient of variation (V) between experimental repetitions. The correlation coefficient was used to establish the reliability and validity of F8WT, the results of which were interpreted based on the experimental factor in accordance with the numerical values obtained.

The time taken to cover the F8W distance, the number of F8W steps, and the speed of F8W performance were dependent variables. The significance level was set at $p<0.05$.

Mathematical statistics methods were used to process, analyze, and interpret the experimental data using SPSS Version 22.0 (IBM Corporation).

Results

In conducting the experimental study, we were guided by the thesis that accurate control of balance and gait parameters is the basis for assessing the risk of injury after blast TBI (Sepehry, Schultz & Mallinson, 2024).

The results of our scientific research are presented in a developed analytical programmable tool for implementing F8W. The central element of the developed tool is a wireless autonomous data collection system. The latter is based on an inertial measurement unit, a sensor system with a neural network and a processing unit, and a Portenta H7 controller, which combines the advantages of technological integration and artificial intelligence.

The inertial measurement unit consists of gyroscopes, accelerometers, and inclinometers (Mykytyuk et al., 2024). These components work together to give us a complete understanding of the student's movement over the distance. Using such a unit provides continuous measurements, making them ideal for tracking movement or body segments in space, for calculating position, speed, and orientation over time.

A distinctive feature of the wireless autonomous data collection system is its flexibility to changing operating conditions, which is critical in dynamic environments. This ensured accurate measurements during the student's movement while performing F8W.

The combination of sensors in the inertial measurement unit is implemented at several levels based on artificial intelligence: obtaining data from several sensors, integrating processed data from different sensors, and combining conclusions made by individual sensor systems (Mykytyuk et al., 2021).

The next element of the developed analytical programmable tool for implementing F8W is a system of sensors with a neural network and a processing unit, which are located along the test distance. The sensor system includes acoustic sensors, spatial position sensors, and proximity sensors. Such a system is an intelligent source of information of a new generation, characterized by high accuracy and stability of measurements at any distance and under any conditions.

The new original Portenta H7 controller is one of the latest platforms focused on low power consumption, high computing power, machine learning capabilities, and real-time communication. The Portenta H7 design involves the use of machine learning algorithms and streaming video. A distinctive feature of Portenta H7 is its high performance and computing speed.

The developed analytical programmable tool for F8W implementation is used as follows (fig. 2.). An inertial mea-

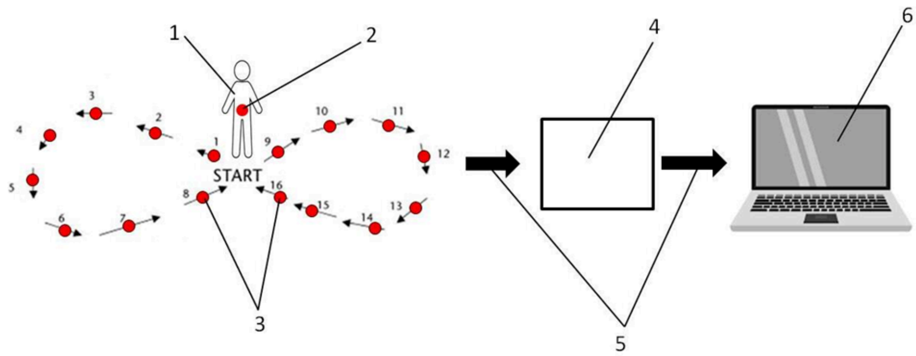

Fig. 2. Scheme of Figure-of-8 Walk implementation using a: 1 – student, 2 – inertial measurement unit, 3 – sensor system, with a neural network and processing unit, 4 – microcontroller platform, 5 – infrared communication lines, 6 – PC

Table 1. Reliability of the of the F8W for students who had suffered war-related injuries (n = 28)

Statistical parameters	Test tasks stepping and measurement results					
	F8WT time (sec)		F8WT steps (number)		Pace (number/sec)	
	T	DT	T	DT	T	DT
M	8.55	8.22	15.7	14.4	1.83	1.75
S	1.31	0.73	2.11	1.92	0.29	0.35
V (%)	29.4	21.7	27.5	20.1	31.0	20.5
			Rtt			
reliability	0.401	0.902	0.352	0.855	0.378	0.885
validity	0.255	0.599	0.227	0.581	0.217	0.613

surement unit is placed on the body of the student performing F8W. In real time, signals measuring the student's acceleration, speed, and position are transmitted via Bluetooth. As the student moves along the distance, the sensor system, with a neural network and processing unit, records information about the student's movement along the distance in real time and transmits it to the microcontroller platform.

The central computing element of the developed device is the Portenta H7 microcontroller platform, which performs the functions of collecting test parameters from the inertial measurement unit and sensor system with flexible activation, data buffering support, wireless transmission, and adaptation to various conditions of use.

The wireless autonomous data collection system, having received the initial control data during the student's performance of the F8W, provides their visualization on the PC screen, auditory feedback through voice outputs, or vibrotactile feedback to the inertial measurement unit.

In the second stage of our research, the developed analytical programmable tool for implementing F8W was tested in practice. The empirical data obtained are presented in Table 1.

According to the data obtained, which underwent statistical verification, the effectiveness of using the analytical programmable tool for implementing F8W is confirmed by the numerical values of the correlation coefficient (Rtt), which were found to be "high" in determining the reliability and validity of F8W.

In contrast, when the results were recorded with a stopwatch, the reliability and validity values of F8W for students who had suffered war injuries were at the «low» and «acceptable» levels.

Discussion

The level of physical activity is determined by factors that determine the quality of life related to the health status of various categories of individuals, such as military personnel (Krushynska, Kohut & Goncharenko 2023; Leland et al., 2016), veterans with disabilities (Brittain & Green, 2012; Caddick & Smith, 2014; Shirazipour, Aiken & Latimer-Cheung, 2017), individuals with blast TBI (Lorenz et al., 2018; Blavt & Gurtova, 2024). In turn, we agree with our own research (Pellerin, Wilson & Haegele, 2022; Kuntjoro et al., 2022; Lieberman, Houston-Wilson & Grenier, 2024) that the quality of inclusive physical education is recognized as a factor in restoring students' health.

Our research is supported by information that innovative technologies currently play an important role in inclusive physical education (Toto et al., 2024; Li, 2025; Adeleye, Eden & Adeniyi, 2024). We agree with the opinion (Alashram, Padua & Annino, 2022; Jamieson & Wijesundara 2025; Chaparro-Cárdenas et al., 2018) that the use of innovative technological tools, in particular AI (Rosa, 2025; Chao, Yi, Min & Long, 2024), has the potential to improve the management of complex injuries and conditions, making it more efficient and effective (Brassel et al., 2021; Pilipović et al., 2025).

According to the results of research (O'Neil et al., 2019; Romeu-Mejia, Giza & Goldman, 2019), the introduction of innovative technologies into the process of restoring bodily functions lost as a result of trauma has been expanded. These technologies make it possible to individualize this process (Farid et al., 2020; Vander Vegt et al., 2022) and objectify functional assessment (Marmor et al., 2022; Santilli et al., 2025; Wellons et al., 2022) based on individual monitoring (Blavt et al., 2023; Jagos et al., 2017; Zhong et al., 2025). Thus, information on vestibular rehabilitation (Galeno et al., 2022; Jantz, Davies & Bigler, 2014; Kalderon et al., 2024) and gait parameter control as a correlator of the vestibular apparatus (Thorman et al., 2022; Wellons et al., 2022; Blavt et al., 2024).

Our study is consistent with information (Willingham et al., 2024; Kalderon et al., 2024) on the formation of research directions that will shape the future of strategies for the precise care of people with disabilities. In particular, AI is emerging as a promising tool for addressing these issues (Rosa, 2025; Jones, DeRuyter & Morris, 2020), including in rehabilitation after TBI (Pilipović et al., 2025).

We support scientific approaches (Jamieson & Wijesundara 2025; Santilli et al., 2024; Zhou et al., 2024) that the dynamic relationship between AI and the health recovery process of people with disabilities continues to evolve, offering future opportunities to increase inclusiveness in physical education for students based on monitoring and assessment data (Wu et al., 2025; Perdomo & González, 2025; Vasco Delgado et al., 2025).

The reliability of F8W has been investigated in populations of older adults (Hess et al., 2010; Coyle et al., 2020; Nualyong & Siriphorn, 2022); adults aged 60–69 years of different gender groups (Jude & Muskaan, 2024); with stroke (Wong, Yam & Ng, 2013; Horata et al., 2025; Kim & Lim, 2012), in neurological disorders (Triolo et al., 2025), with Parkinson's disease (Lowry et al., 2022; Soke et al., 2023); with multiple sclerosis (Fatih et al., 2022; Katirci Kirmaci et al., 2023).

F8W was tested for the first time to monitor the mobility of students who had suffered war-related injuries in inclusive physical education, and an intelligent programmable tool developed for F8W was also used for the first time.

Conclusions

War is usually associated with life-threatening situations, which in turn cause a whole range of injuries to both military and civilian personnel. In the current war with russia, many Ukrainian military and civilians are injured, in particular as a result of blast waves or artillery shells. The war in Ukraine, which has been going on for more than 10 years, despite being a significant and ambiguous layer of history, is a driving force for science.

To ensure the reliability of F8W in inclusive physical education in terms of impartiality and timeliness of control data, an analytical programmable tool has been developed for students who have suffered injuries as a result of the war. The design solution of the analytical programmable tool presented in the work involved the use of an inertial measurement unit and a microcontroller platform using machine learning. We used the combination of sensors in a measuring unit based on artificial intelligence and machine learning as a modern, powerful approach to maximizing the advantages, with the possibility of local execution of algorithms for recognizing student movement patterns during exercise.

The research proved that the developed tool for analyzing the mobility parameters of students who have suffered war injuries in real time is characterized by excellent accuracy and reliability of measurements. The effectiveness of F8W measurement was confirmed based on statistical analysis. At the same time, the low level of reliability and validity of measurements using traditional means has been proven, which is obviously due to the influence of the human factor.

In conclusion, we have grounds to conclude that the introduction of modern technologies into the process of monitoring inclusive physical education of students who have suffered war-related injuries has significant advantages over traditional methods of recording test results.

Conflict of Interest

The author declares no conflict of interest with any other authors or related research findings.

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Аналітичний програмований засіб покращення достовірності тесту ходьби за схемою «вісімка» у інклюзивному фізичному вихованні

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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., 2 рис., 69 джерел.

Мета дослідження полягала в установлення достовірності тесту ходьби за схемою «Вісімка» у інклюзивному фізичному вихованні з використанням розробленого аналітичного програмного засобу.

Матеріал та методи. Дослідження реалізовано на теоретичному та емпіричному рівні. Педагогічний експеримент передбачав використання тесту ходьби за схемою «Вісімка». Досліджувана вибірка складалась із 28 студентів 1-го курсу після легкої вибухової черепно-мозкової травми та після легкої вибухової черепно-мозкової травми, ускладненою акуботравмою, які набули травми внаслідок війни.

Результати. Результати нашого наукового пошуку представляємо у розробленому аналітичному програмованому засобі для реалізації тесту ходьби за схемою «Вісімка». Центральним елементом котрого є бездротова автономна система збору даних, яка побудована на базі інерційного вимірювального блоку, системи датчиків з нейромережею, блоку обробки та контролеруPortenta H7 й яка акумулює переваги технологічної інтеграції та штучного інтелекту.

Інерційний вимірювальний блок розміщується на тілі студента, який виконує тест ходьби за схемою «Вісімка». В реальному часі сигнали вимірювання прискорення, швидкості та положення студента з наступною передачею даних через інтерфейс Bluetooth. При пересуванні студента по дистанції, система датчиків, з нейромережею та блоком обробки фіксує інформацію, про переміщення студента по дистанції в реальному часі та передає на мікроконтролерну платформу Portenta H7, яка виконує функції збору інформації з інерційного вимірювального блоку та системи датчиків з гнучкою активацією. Бездротова автономна система збору даних отримавши вихідні дані контролю при виконання студентом тесту, забезпечує їхню візуалізацію на екрані персонального комп'ютера.

Відповідно до отриманих даних, що пройшли статистичну перевірку, ефективність використання аналітичного програмованого засобу для реалізації тесту ходьби за схемою «Вісімка»засвідчено числовими значеннями показників надійності та валідності на рівні «високий» Водночас установлено низький рівень надійності та валідності вимірювань з використанням традиційних засобів внаслідок впливу людського чинника.

Висновки. Реалізованим дослідженням доведено, що розроблений засіб для аналізу параметрів мобільності студентів, які отримали травми внаслідок війни, в режимі реального часу характеризується високим рівнем достовірністі вимірювань з використанням тесту ходьби за схемою «Вісімка» та має значні переваги порівняно з традиційними методами фіксації результатів тестування.

Ключові слова: студент, травми війни, фізичне виховання, інклюзія, контроль, тестування, тест ходьби за схемою «Вісімка», достовірність.

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Cite this article as: Blavt, O., Lei, S., Helzhynska, T., Pityn, M., Herasymenko, O., Vovk, I., Prozar, M., & Hrebik, O. (2025). An Analytical Programmed Tool for Improving the Reliability of the Figure-of-8 Walk Test in Inclusive Physical Education. Physical Education Theory and Methodology, 25(6), 1426-1434. https://doi.org/10.17309/tmfv.2025.6.13

Received: 08.11.2025. Accepted: 27.11.2025. Published: 30.11.2025