



ORIGINAL SCIENTIFIC ARTICLE

## THE EFFICIENCY OF THE APPLICATION OF ELECTRONIC TECHNIQUES IN THE CONTROL OF DYNAMIC BALANCE IN THE PROCESS OF INCLUSIVE PHYSICAL EDUCATION

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### Abstract

**The purpose of the study** was to determine the authenticity of the dynamic balance control device developed on the basis of modern trends in the field of electronic equipment for students with disabilities.

**Materials and methods.** 32 students with disabilities, aged 18–24 years, I–III years of study, who received a doctor's permission to participate in testing and had vestibular disorders, were selected for the studied sample, in accordance with the provisions of voluntariness and anonymity. General scientific methods of gathering theoretical information, the method of technical modeling, pedagogical testing and methods of mathematical statistics were used.

**Results.** A dynamic balance control device was developed on the basis of the most up-to-date electronic equipment and programming. The device consists of an integrated electronic unit, a programmable microcontroller system unit, and a PC. The information received by the capacitive sensors placed in the unit of the integrated electronic unit during the student's performance of the test task is processed in the unit of the programmable microcontroller system and transmitted via non-contact infrared communication lines to the PC where it is graphically presented. To establish the authenticity of testing using the developed device, reliability and validity coefficients were determined, which in numerical values reached a "high" level, in contrast to the test the results of which were recorded directly by the teacher and numerically corresponded to the limits of "low" and "medium".

**Conclusions.** The dynamic balance control device presented in the work is designed using the most up-to-date electronic equipment and programming. Considering the importance of eliminating vestibular disorders and related dynamic balance disorders in students with disabilities, the use of the presented development of the control device in the practice of inclusive PE is aimed at ensuring the effectiveness of this process. The integration of a control device developed based on current trends in the field of electronic equipment into the inclusive physical education of students with disabilities is the basis for the development of new approaches in the process of dynamic balance testing based on objective assessment.

**Keywords:** students with disabilities, physical education, testing, inclusion, control, electronic equipment, dynamic balance.

### Introduction

Problem statement. The invasion of the Russian Federation into Ukraine increased attention to a number of impor-

tant issues in the field of higher education at the global level. In particular, ensuring the quality of the educational process for students with disabilities is associated with several problems that have worsened under martial law. Given the development of events regarding the duration of the military aggression of the Russian Federation, the number of such persons will increase. Therefore, the problem of physical and psychological rehabilitation of students with disabilities dur-

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ing their studies in higher education institutions is gaining considerable relevance.

In ensuring the full-fledged life activities of students with disabilities in higher education, a significant place is given to the potential of inclusive physical education (PE) (Haegele & Sutherland, 2015). Adaptation of this process to today's requirements, and its modernization, which ensures the process of correction of health disorders of students with disabilities, is of particular importance.

Since the experience of inclusive PE in higher education institutions is practically absent in Ukraine, the development of this direction as a factor in health preservation and rehabilitation of persons with disabilities is currently one of the priority tasks of the educational policy of higher education.

Analysis of recent research and publications. First of all, we should note that the national doctrine of education development in Ukraine in the 21st century defines that the main factor in the development of education should be innovative activity (Mykytyuk et al., 2022). The issue of the necessity and significance of innovative processes in inclusive education is reflected a number of scientific works (Goodwin & Watkinson, 2000; Lidor & Hutzler, 2019; Page, Anderson, & Charteris, 2021; Grenier, Patey, & Grenier-Burtis, 2022).

It is believed (Haegele & Sutherland, 2015), that solving the problem has a multidisciplinary basis. According to specialists (Pocock & Miyahara, 2018), the effective here is the inclusive PE of students with disabilities using forms, means, and methods of PE (Ivashchenko, 2020) in a complex with the latest advances in electronic techniques (Gogoi, 2019; Gupta, 2021).

There is no doubt that the goals of modern inclusive PE require the latest technologies (Kuntjoro et al., 2022). Currently, considerable experience has been accumulated in this field of knowledge, which proves the role of unified electronic techniques, which are constantly developing almost every day (Blavt et al., 2022). Researched, that a wide range of electronic techniques, covering any procedures, providing storage, receiving, manipulation, and transmission of information in electronic form in digital form (Klavina, 2011; Koryahin et al., 2022), open significant new opportunities for evaluating the effectiveness of the PE process.

A significant percentage of students with disabilities now have vestibular disorders, which can be the result of numerous diseases or craniocerebral injuries. If disease or injury damages the vestibular system, balance and postural control disorders, problems with stability and coordination of movements, dizziness, etc. can occur (Voronova et al., 2021). A consequence of vestibular dysfunction can be cognitive and communicative disorders, concentration difficulties, etc., which, accordingly, creates difficulties in the learning process (VeDA). Such disorders are characterized as brain "fatigue" syndrome, which is accompanied by various cognitive disorders (Hall et al., 2016). In addition, emotional disorders, which are very relevant in the conditions of prolonged stress of war, indirectly affect gait and balance (Da Cruz et al., 2010; Gurgel et al., 2012).

Correction and elimination of vestibular disorders, as a science-based area of PE practice, is aimed at the effective management of vestibular symptoms (Herdman, 2013;

Fitzgerald, 2006). Assessment of the process of correction of vestibular disorders should include assessment of balance and dynamic coordination (Dunne et al., 2023). From the standpoint of pedagogical science regarding the organization of the educational environment in higher education, but with an emphasis on taking into account the determinants and model of inclusive education in a complex with modern advances in electronic techniques and software in the process of correction and elimination of vestibular disorders are very timely.

The purpose of the research was to determine the authenticity of the dynamic balance control device developed based on modern trends in the field of electronic techniques for students with disabilities.

## Materials and methods

### Research methods

The conducted research involved implementation in three stages: development of the device, collection of empirical data, and mathematical processing. To formulate reliable, relevant research answers, methods based on interdisciplinary strategies were chosen in the implementation of the research. Along with general scientific methods, methods evolved from other disciplines were used to obtain theoretical and empirical material (analysis, synthesis, and generalization). The method of technical modeling was used to create a test control device that was subject to study. In addition, the method of pedagogical experiment and mathematical methods of descriptive statistics were applied, which were used to formulate conclusions based on an accurate description of the data obtained.

For individuals with vestibular problems and dynamic balance assessment, the Four Square Step Test (Four\_Square\_Step\_Test) was used. The testing procedure involves stepping through the membranes forward, sideways and backwards (Fig. 1). Description of the test: the student must successively step over four membranes set with a cross on the ground. At the beginning of the test, the student stands in square 1 facing square 2. The goal is to enter each square as quickly as possible with both feet in the following sequence: square 2, 3, 4, 1, 4, 3, 2, 1 (clockwise counterclockwise arrow). During the test, the student must be in a standing position on two legs in each square. Two attempts are made and the best time (in seconds) is taken as the score. Both feet should touch the floor in each square. The attempt is considered unsuccessful if the student fails to complete the sequence, loses balance, contacts the membrane.

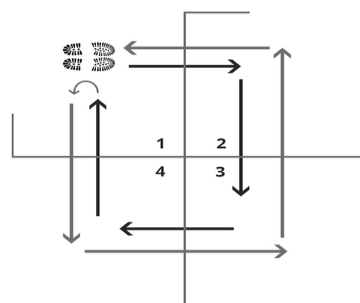


Fig. 1. Scheme of the test

### Study participants

The research sample consisted of 32 students with disabilities who met the inclusion criteria (had vestibular disorders) for the study. Written consent to participate in testing was obtained from each of the research participants.

The condition for participation in the experiment was the stability of the condition, the absence of pronounced symptoms of exacerbation of vestibular disorders, or the main disease at the time of screening and data collection. The research sample was formed from equal numbers of men and women aged 18 to 24 years, I-III courses of study Lviv Polytechnic National University, Kamianets-Podilskiy Ivan Ohienko National University and Lutsk National Technical University, who received a doctor's permission to participate in testing. During the process of obtaining informed consent, students were informed that in the event of inappropriate reactions (dizziness, rapid heart rate, etc.), the test procedure was terminated.

The study was carried out in accordance with the provisions of voluntariness and anonymity. All test participants gave written consent to participate in the experiment. 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".

The provisions of voluntariness and anonymity carried out the study. All test participants gave written consent to participate in the experiment.

### Research organization

The collection of empirical data on students' performance of the test task was implemented in two ways of recording the result. One was carried out with the participation of a specialist who used a stopwatch and visual control, the other – with the help of a developed control device. To ensure the reliability of the experiment, testing was carried out during three months of the academic semester, trying to ensure the same conditions. The test participants were given precise instructions and formulated tasks.

### Statistical analysis

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

To determine the quality and applicability of the developed control device in the practice of inclusive PE, the characteristics of the study's compliance with the formal criteria of authenticity - reliability and validity of the test were calculated. As complementary indicators, they are used as an assessment of the reliability and significance of research results.

The test is considered reliable only if it provides high measurement accuracy (Magill, & Anderson, 2017). Reliability as validity was measured by retesting the same test subjects no later than two weeks after the first test.

Given that the test results are presented quantitatively, a correlational study was used to determine the specified test characteristics of authenticity (reliability and validity) and

to investigate the relationship between the variables without control or manipulation by the researcher (Bhandari, 2023).

To determine the degree of correlation between different measurements for testing new means of measuring variables, it is recommended to use correlation analysis, at the same time, such analysis is considered ideal for rapid data collection in natural conditions (Turney, 2022).

### Results

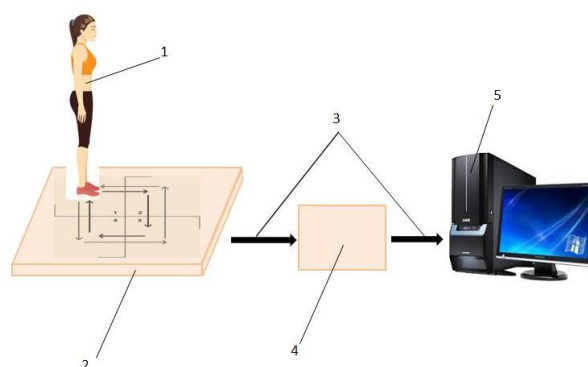
First of all, we note that vestibular disorders cause a lot of discomfort to students with disabilities. Constant dizziness and migraines, difficulty maintaining balance while walking and other functional movements, such as getting up from a chair, reduced work capacity, and even the fact that they can cause accidents. Balance is most directly affected by postural disturbances when the center of gravity shifts (Voronova, Lazareva, Kovelska, & Kobinskyi, 2021).

The main problem of test control of dynamic balance using the test is to ensure standardization of the testing procedure and fixation of results. Our research was aimed at eliminating subjectivity in these operations to ensure the objectivity of the control and the reliability of the obtained results. This is important because they are the basis for the correction of individual programs of inclusive PE (Blavt, 2022).

Therefore, we have developed a dynamic balance control device for students with disabilities. The device consists of an integrated electronic unit, a programmable microcontroller system unit, and personal computer (PC). Signals in the device are transmitted by infrared communication lines (Fig. 2).

The basis of the device is an integrated electronic unit, which is built based on the use of sensor electronics, which is now widely used in modern smart systems. The function of the integrated electronic unit consists of non-contact measurement of the position of the legs during the test, movement dynamics, turning angles during walking, as well as the accuracy of the test task.

Capacitive sensors form the basis of the integrated electronic assembly. Capacitive sensors, which function according to the principle of non-contact capacitive tomography (Wojcik, Vistak, Mykytyuk, Politanskyi,



**Fig. 2.** Scheme of the developed dynamic balance control device: 1 – student, 2 – integrated electronic unit, 3 – infrared communication lines, 4 – programmable microcontroller system unit, 5 – PC

Diskovskiy, Sushynskiy, Kremer, Prystay, Jaxylykova, & Shedreyeva, 2020), are placed in a block of integrated electronic assembly, made in the form of a square. Along the perimeter of the square, there are electrodes of spatial scanning capacitive sensors, and inside the square – a two-coordinate sensor matrix for detecting surface pressure. The two-coordinate matrix records the position of the student’s legs when performing the test exercise, as the main parameter of dynamic balance. Such a sensor matrix, ensuring the fixation of footprints on its surface, allows to determine their position on the measuring plane during the performance of the test task.

An important parameter of the capacitive sensor electrodes used in the developed device is the measurement speed. In the integrated electronic combination, the speed of operation is 100.000 measurements per second. In terms of image acquisition time, this provision has a throughput of several hundred frames per second and a data processing time of only a few milliseconds per frame. The range of pressure measurement on the surface allows you to identify the position of the feet of student of all weight categories. The measurement is made at a speed of 6 frames per second.

Further, informative signals measurement are transmitted to the block of the programmable microcontroller system, and then to the PC. The signals received in the PC are processed by the software developed for the implementation of the device.

The next stage of the experimental research involved testing and determining the authenticity of the test using various means of recording the result (Tab. 1, 2). To ensure the reliability of the experiment, testing was carried out three times.

Establishing the authenticity of the test, using the fixation of the results with a stopwatch, proved that the reliability according to numerical indicators corresponds to the limits of low and medium. The validity of these tests is within the same limits. The presence of a fairly high coefficient of variation, which characterizes the range of differences, draws attention. Indicators of the coefficient of variation within the limits of significant variation for all the studied parameters indicate that the stability of the results in the studied sample is lower than the metrological norms of reliability.

According to the results of the statistical processing of the results, the use of the developed device provides a high level of authenticity, which is reflected in the reliability and validity indicators. Such results, in comparison with the

**Table 1.** Results of dynamic balance testing with stopwatch fixation (n = 32)

Statistical parameters	Test tasks and measurement results (s)					
	1 <sup>st</sup> attempt		2 <sup>st</sup> attempt		3 <sup>st</sup> attempt	
	male	female	male	female	male	female
M	4.2	5.1	4.3	4.9	4.7	5.5
S	0.85	1.1	1.2	1.3	0.87	1.7
V (%)	31.5	34.5	30.5	35.8	32.1	36.1
rtt						
reliability	0.702	0.612	0.712	0.641	0.718	0.691
validity	0.295	0.281	0.305	0.290	0.317	0.233

**Table 2.** Results of dynamic balance testing with fixation by an electronic control device (n = 32)

Statistical parameters	Test tasks and measurement results (s)					
	1 <sup>st</sup> attempt		2 <sup>st</sup> attempt		3 <sup>st</sup> attempt	
	male	female	male	female	male	female
M	4.11	4.89	4.17	4.51	4.05	4.33
S	0.71	0.91	1.01	0.83	0.79	1.12
V (%)	23.4	25.1	23.9	26.1	22.5	26.3
rtt						
reliability	0.818	0.812	0.842	0.817	0.911	0.893
validity	0.388	0.401	0.390	0.395	0.417	0.393

fixation of results in the traditional way using a stopwatch, when the quantitative values of authenticity, are significantly inferior to those obtained from the use of the developed device. The obtained numerical indicators of authenticity reached the level and “high level”, and even “very high”.

In addition, the use of the developed device allows you to record test results with an accuracy of seconds, which is a powerful factor in ensuring the reliability of the assessment. Thus, the digitization of testing, providing direct feedback with assessment.

The software has been developed to digitize test results. Using programming, they ensured the formation of a test control database. Accumulation, updating and graphic presentation of test control information made possible the efficiency of analysis with the results of test control. In the database, archiving of test counter data in the infrastructure of data storage and processing centers was provided in a personal text format for each student and is available to them.

## Discussion

It is the need of the hour to organize the educational and educational process of PE in higher education, which would meet the educational needs of all students with disabilities without exception (Grenier, Patey, & Grenier-Burtis, 2022; Pocock & Miyahara, 2018; Blavt et al., 2023). This issue requires an effective and quick solution, taking into account the rapid increase in the number of students with disabilities since the full-scale invasion of russia on the territory of Ukraine, and the duration of hostilities, to eliminate the limitations of their educational opportunities and health care (Blavt, Bodnar, Mykhalskyi, Gurtova, & Tsovk, 2023).

Scientific developments related to the modernization of inclusive PE are aimed at combining classes in useful proportions and methods of monitoring their effectiveness (Baglieri & Bacon, 2020; Sawade, 2023; Qi & Ha, 2012). We support scientific approaches (Gogoi, 2019; Koryahin et al., 2020; Varga & Révész, 2023), regarding the need to raise the level of scientific research in physical education, integrating them into the global practice of informatization. As mentioned (Mykytyuk et al., 2022; Gupta, 2021), the use of modern electronic resources on the basis of permanent informatization of PE is recognized as a key factor in ensuring the quality and efficiency of PE.

Focusing on changes in the current understanding and practices of inclusive PE to correct health disorders of students with disabilities, vestibular disorders are widely understood

as those that determine the quality of daily life (Gurgel et al., 2012). A special place in this process is occupied by the functions of walking and maintaining balance (Voronova et al., 2021) and body stability, for example, while standing and sitting. Given the relevance of the topic, we draw attention to the proven significant connection between the presence of emotional disorders and the way of life and work of the vestibular apparatus (Da Cruz et al., 2010). The obtained empirical results (Hall et al., 2016; Herdman 2013), of the experiment confirm the dependence of dynamic balance on the functional state of the vestibular apparatus and the presence of functional disorders, which is obviously a factor in the variation of results in retests.

The practical value of the control device presented for the first time in the work lies in the possibility of its application to persons with amputated limbs. We agree that in this case (Koryahin et al., 2020; Rum et al., 2021), electronic techniques of control are not only a technological method of scientific research, a source of supplying new information, knowledge and ensuring interdisciplinary interactions, but also a method of forecasting and prediction.

## Conclusions

In the process of ensuring quality education for students with disabilities, a special place is given to effective inclusive physical education in institutions of higher education, whose number is permanently increasing. In the national-state dimension, the actualization of the content of inclusive PE is determined by the challenges caused by the growth of requirements to ensure the effectiveness of the educational field of knowledge in the aspect of national health preservation.

The use of innovative technologies in inclusive physical education is positioned in the interdisciplinary plane. The dynamic balance control device presented in the work is designed using the most modern electronic techniques and programming. Considering the importance of eliminating vestibular disorders and associated disorders of balance and coordination of movements, the use of the presented development in the practice of inclusive PE of students with disabilities is aimed at ensuring the effectiveness of this process.

The degree of authenticity of the developed dynamic balance control device for students with disabilities was experimentally investigated. According to the statistical analysis, in the digital values, the indicators of reliability and validity reached the “high” level, in contrast to the studied indicators obtained by the traditional method, which were recorded at the “acceptable” and “average” levels.

Among the advantages of the developed control device, we single out: simplicity and ease of use, achieving objectivity of control, devoid of subjectivity in recording results, promptness of the obtained results and their evaluation, suitability of test control results for automated processing and use of statistical methods, archiving and saving in the database. The efficiency of the test process and obtaining information in digital form are valuable aspects of the implementation of the development in the practice of inclusive PE for students with disabilities.

## Conflicts of interest

No conflicts of interest exist.

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## ЕФЕКТИВНІСТЬ ЗАСТОСУВАННЯ ЕЛЕКТРОННОЇ ТЕХНІКИ У КОНТРОЛІ ДИНАМІЧНОЇ РІВНОВАГИ В ПРОЦЕСІ ІНКЛЮЗИВНОГО ФІЗИЧНОГО ВИХОВАННЯ

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

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**Мета дослідження** полягала у визначенні автентичності розробленого на основі сучасних трендів в галузі електронної техніки пристрою контролю динамічної рівноваги студентів з інвалідністю.

**Матеріал та методи.** До досліджуваної вибірки, відповідно до положень добровільності та анонімності, були добрані студенти з інвалідністю віком 18-24 роки I-III курсів навчання, які отримали дозвіл лікаря на участь у тестуванні та мали вестибулярні порушення. Використано загальнонаукові методи збору теоретичної інформації, метод технічного моделювання, педагогічне тестування й методи математичної статистики.

**Результати.** Розроблено пристрій контролю динамічної рівноваги на основі найсучаснішої електронної техніки та програмування. Пристрій складається з блоку програмованої вбудованої мікроконтролерної системи, джерела живлення, ПК, блоку інтегрованого електронного об'єднання. Інформація, отримана сенсорами, розміщеними у блоці інтегрованого електронного об'єднання при виконанні студентом тестового завдання, обробляється мікроконтролером та передається безконтактними лініями інфрачервоного зв'язку на ПК, де графічно представляється. Для установа автентичності тестування з використанням розробленого приладу, було визначено коефіцієнти надійності та валідності, які у числових значеннях досягли «високого» рівня, на протигаву тесту, результати якого фіксувались безпосередньо викладачем з використанням секундоміра й за числовими показниками відповідні межах «низької» та «середньої».

**Висновки.** Представлений у роботі пристрій контролю динамічної рівноваги сконструйовано з використанням найсучаснішої електронної техніки та програмування. Зважаючи на важливість усунення вестибулярних розладів та пов'язаних із ними порушень динамічної рівноваги у студентів з інвалідністю, використання презентованої розробки пристрою контролю у практиці інклюзивного ФВ скеровано на забезпечення ефективності цього процесу. Інтеграція у інклюзивне фізичне виховання студентів з інвалідністю пристрою контролю, розробленого на основі сучасних трендів в галузі електронної техніки, є основою розроблення нових підходів у процесі тестування динамічної рівноваги на основі об'єктивного оцінювання.

**Ключові слова:** здобувачі вищої освіти з інвалідністю, фізичне виховання, тестування, інклюзія, контроль, електронна техніка, динамічна рівновага.

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