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TEST CONTROL OF INCLUSIVE PHYSICAL EDUCATION: ASSESSMENT USING THE NEWEST ELECTRONICS

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Abstract

The purpose of the study was to determine the effectiveness of a device developed based on the latest electronics to control the coordination of movements of the lower limbs of students with disabilities.

Materials and methods. 34 students with disabilities were involved in the study. At the time of the experiment, they had functional disorders of the lower limbs as a result of injuries and received a doctor's permission to participate in the experiment. The research was conducted at the theoretical and empirical levels, using the following methods: analysis, synthesis, systematization, generalization, technical modeling, pedagogical testing, and mathematical statistics.

Results. In the research process, a device was used, which was developed as part of the conducted research. The device consists of two rubber mats in which capacitive proximity sensors are placed. The test task involves recording the number of touches of rubber mats in 20 seconds. The information received from the sensors during the student's performance of the test task, namely the alternate touching of the rubber mat with the big toe, is sent to the microcontroller via an infrared communication line. The development uses a high-performance microcontroller ATMega 328P, which can support a wide range of sensors and generate information about the time and frequency of leg movements. The signals of the student's toes touching the rubber mats, received by capacitive sensors, are processed by a microcontroller and displayed on a PC through a serial connection and using the Arduino software, which allows reading the received information about the execution of movements. Under the conditions of the pedagogical experiment, we tried to determine the quality of the measurement results. According to the obtained numerical indicators, the numerical values of the test authenticity obtained by the traditional method of fixing the results by a specialist correspond to the value "low". The results of the validity calculations showed that the correlation between the test measurement results and the evaluation results using the developed device was optimal with a correlation coefficient greater than 0.6.

Conclusions. The importance of a high level of development of the coordination of movements of the lower limbs of students with disabilities is determined by the need to develop this quality to ensure the effectiveness of their rehabilitation in the process of inclusive PE. The analysis of the obtained material allows us to state that the practical application of the inclusive PE device developed based on the latest electronics will allow scientifically based optimization of this process to ensure its effectiveness.

Keywords: students with disabilities, physical education, testing, inclusion, control, coordination of lower limb movements.

Introduction

Problem statement. Russia's open military attack on Ukraine in 2022 and long-term Russian aggression have become a factor in the fact that the number of people affected by the war in Ukraine is constantly increasing. It is natural that among the entrants to higher education institutions, the number of persons with disabilities who received injuries and permanent limitations of life activities as a result of participation in hostilities and emergencies increases annually (Blavt, Bodnar, Mykhalskyi, Gurtova, & Tsovkh, 2023).

In connection with the latter, the process of attracting and preventing the exclusion of students with disabilities from the conditions of study in the process of obtaining higher education – their successful inclusion – acquires special significance (Page, Anderson, & Charteris, 2021). Since the full-scale invasion of Russia on the territory of Ukraine, attention has increased to the problems of inclusion of students with disabilities, which today is one of the most pressing issues of higher education (Blavt, Iedynak, Pereverzieva, Holub, & Melnyk, 2023).

One of the effective means of inclusion in higher education is considered inclusive PE (Kuntjoro, Soegiyanto, Setijono, & Suhiharto, 2022).

Making qualitative changes in the process of inclusive FP for its productive development requires constant monitoring of the expediency of using a wide range of FP tools (Hutzler, & Levi, 2008). In this aspect, the synergy of efforts of different fields of knowledge involves the use of high-tech measuring devices, which allows for quantitative evaluation of the results of inclusive PE (Mykytyuk, Blavt, Hnatchuk, Stechkevych, & Helzhynska, 2022).

Analysis of recent research and publications. The scientific interest of researchers from different countries of the world is focused on the possibilities of inclusive PE as an effective means of preserving the health, well-being, and inclusion of persons with disabilities (Pocock, & Miyahara, 2018; Wilhelmsen, & Sørensen, 2017; Nemček, 2022). Currently, there is a fairly wide list of empirical studies (Baglieri, & Bacon, 2020; Grenier, Patey, & Grenier-Burtis, 2022; Pellerin, Wilson, & Haegele, 2022) regarding the value of inclusive PE in the implementation of rehabilitation of students with disabilities.

According to data from scientific sources (Nanayakkara, 2022; Grenier, Patey, & Grenier-Burtis, 2022; Wolbring, & Lillywhite, 2021), inclusive PE for students with disabilities who have suffered injuries is a means of preventing serious mobility limitations, postural disturbances, reduced body endurance and inability to tolerate physical exertion. According to ideas (Davis, Rocco-Dillon, Grenier, Martinez, & Aenchbacker, 2012; Desrosiers, Rochette, & Corriveau, 2005), an important place in this process to increase the chances of maximum recovery and return to a comfortable physical state of students with disabilities is the coordination of lower limb movements.

The importance of lower limb motor coordination is because it enables the performance of most daily motor activities, such as walking, running, climbing/descending stairs, and standing from a chair (Lower_Limb_Motor_Coordination). According to available research (Pinheiro, Scianni, Ada, Faria, & Teixeira-Salmela, 2014), the coordination of lower limb movements is a factor affecting the effectiveness of the rehabilitation process, as a result of its violation, problems with balance and coordination arise due to disorders of the nervous, vestibular, or supporting – motor system (Neto, Steenbergen, Wilson, Zamunér, & Tudella, 2020).

Monitoring and evaluating the effectiveness of the PE process requires a reliable toolkit (Iermakov, Ivashchenko, Khudolii, & Chernenko, 2020). The mainstream in the creation of measurement tools based on high-tech capabilities is the latest electronic technologies (Blavt, Chaplinskyi, Prozar, Pityn, Helzhynska, Dmytruk, Hrebik, & Kovalchuk, 2023).

Empirical studies (Blavt, Iedynak, Pereverzieva, Holub, & Melnyk, 2023; Kashuba, Nosova, Kolomiets, & Maslova, 2019) have proven the effectiveness of using electronic technologies in monitoring PE results (Gupta, 2021; Gogoi, 2019; Varga, & Révész, 2023; Mykytyuk, Blavt, Kachurak, Stadnyk, Gurtova, Diskovskyi, & Barylo, 2022).

Taking into account the consequences of armed Russian aggression on the territory of Ukraine, which are an increase in students with disabilities who received injuries and permanent restrictions on life, and taking into account the practical value of the experience of using the latest electronics in the process of inclusive PE, the direction of scientific research was chosen.

Purpose of the research research in determining the effectiveness of the device developed based on the latest electronics for controlling the coordination of movements of the lower limbs of students with disabilities.

Materials and methods

Research methods

The methods chosen for the implementation of our scientific research by the purpose and objectives of the research are characterized by systematicity and structure. Therefore, in conducting empirical research, we were guided by a systematic approach (Ivashchenko, 2020). According to this approach, the first stage of the research involved obtaining complete, objective, reliable information about the feasibility of the outlined scientific research – the theoretical level of research implementation, the second – had a comparative view of the researched issue. At the third stage of the research, according to the system approach, the empirical data obtained during the comparison were summarized. The fourth final stage consisted in the formation of generalized results.

The test chosen for the study to monitor the level of development of coordination of movements of the lower limbs (Pribble, Black, Larson, & Larson, 2021) is the simplest and easiest-to-use exercise that does not require complex equipment. The test case must be performed in a sitting position on a chair. The test procedure lasts less than 1 minute, and therefore the possibility of fatigue is excluded.

Test procedure. The student sits on a chair with adjustable height so that the soles of both sides are in contact with the floor. Heels, hips and knees should be in a 90° flexion position. After a trial introduction, the student should alternately touch the disks located on the floor at a distance of 30 cm from each other with his big toe. Movements are

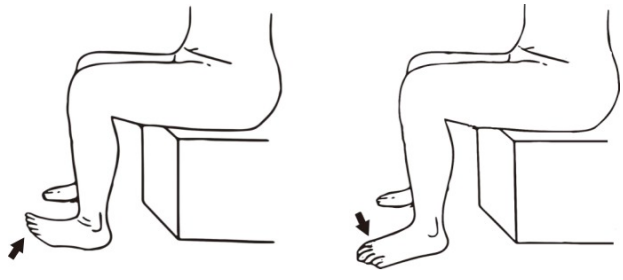

Fig. 1. Scheme of the test

performed for 20 seconds. The number of touches to the discs in 20 seconds is recorded. The toes were required to strike and then "lift-off" the floor during movement.

Study participants

34 students with disabilities were involved in the study Lviv Polytechnic National University, Kamianets-Podilskyi Ivan Ohiienko National University and Lutsk National Technical University, who at the time of the experiment had functional disorders of the lower limbs as a result of injuries or damage. It is important that all participants of the experiment were diagnosed with injuries of moderate severity in a state of remission. A requirement of the experiment at the time of screening and data collection was the absence of acute conditions, open wounds or complications in students with disabilities. The students with disabilities involved in the experiment independently attended the inclusive PE classes within the educational program and did not need outside help in completing the test task.

Written consent to participate in the experiment was obtained from each student who was planning to be involved in the study. To ensure the representativeness of the studied independent sample, several mandatory conditions for any research were taken into account, namely, every student, in the presence of health abnormalities, received an equal probability of becoming a research participant.

A doctor's permission to participate in the experiment was obtained from all students with disabilities who made up the researched sample. First-year students (men) who voluntarily and anonymously agreed to participate in the experiment to eliminate biases in the collection and analysis of information were involved in the experiment.

Taking into account the fact that the degree of authenticity of the test, which is determined empirically, is significantly influenced by the nature of the sample used to test the test, the conditions of performing motor actions, the level of physical fitness of the students of the studied sample, the degree of existing lesions and the degree of injury to the limbs were taken into account, etc.

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

The study was planned and carried out in accordance with the principles of empirical research ethics. The organization of the research involved obtaining empirical facts. The measurement process, to collect empirical test data, is implemented in two ways. First of all, all students with disabilities, who were involved in the experimental study, were given clear instructions on the implementation of the test task.

The experimental factor involved a variation in the method of recording test control results. Fixation of test control results was implemented with the direct participation of a specialist to get rid of the elements of subjectivism of traditional analysis, using the 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. Test participants were provided with precise instructions and formulated tasks.

Statistical analysis

In order to bring the empirical data obtained during the empirical research to a form more suitable for meaningful analysis, a computer type of processing of the obtained empirical information was chosen. All statistical analyses were performed using SPSS Version 22.0 (IBM Corporation).

The conclusion about the results of the empirical study was made based on establishing the authenticity of the tests. Validity, which indicates its usability and reliability, served as a comprehensive characteristics. To establish the quantitative characteristics of the authenticity of the test and in view of the low labor intensity, correlation analysis was applied (Turney, 2022). Correlation analysis involves measuring two variables and assessing the statistical dependence (correlation) between them.

Results

First of all, we note that the proper level of coordination of movements of the lower limbs requires temporal and spatial accuracy of movements and ensures the ability to perform motor tasks while walking in an accurate, fast, and controlled manner (Lower limb motor coordination). In turn, objective timely monitoring of the coordination of movements of the lower limbs allows for a standardized understanding of the nature and level of impairments, to assess the level of recovery progress after the consequences of the injury (Hoenig, Amis, Edmonds, Morgan, Landerman, & Caves, 2018).

In the research process, a device was used, which was developed within the framework of the conducted research (Fig. 2). The device consists of two rubber mats in which capacitive proximity sensors are stirred (Hotra, Mahlovanyy, Mykytyuk, Barylo, Kremer, Ivakh, & Politanskyi, 2019). The test task involves recording the number of touches of rubber mats in 20 seconds. The device registers changes in the capacitance of the sensors when the student touches the rubber mats with his toes. The information received

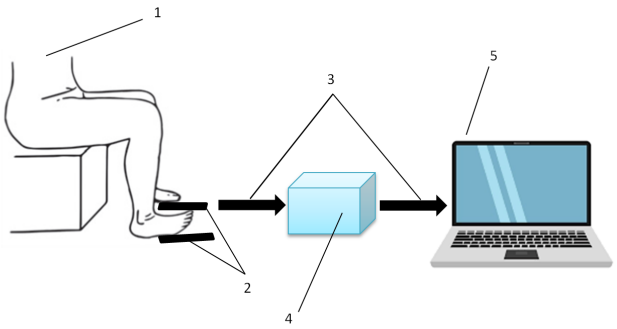

Fig. 2. Scheme of the developed device for controlling the coordination of movements of the lower limbs: 1 – student, 2 – rubber mats, 3 – infrared communication lines, 4 – microcontroller, 5 – PC

from the sensors during the student's performance of the test task, namely the alternate touching of the rubber mat with the big toe, is sent to the microcontroller via an infrared communication line. The microcontroller generates information about the time and frequency of leg movements.

The novelty of the proposed development is that the device uses a high-performance microcontroller ATMega 328P of the "latest generation", which can support a wide range of sensors and has a large list of functions (Mykytyuk, Kremer, Ivakh, Diskovskyi, & Khomyak, 2021). This microcontroller contains an internal built-in 32 kB of flash memory, 23 input/output lines, configurable timers and counters, and 5 possible power-saving modes, with the ability to balance power consumption and performance.

The signals of the student's toes touching the rubber mats, received by capacitive sensors, are processed by a microcontroller and displayed on a PC through a serial connection and using the Arduino software, which allows reading the received information of the test task. The device allows you to record and control not only the number of taps but also their duration, rhythm, speed, etc. And the used software allows you to present it graphically.

The developed device ensures that all test control data is collected, analyzed, and available in a single system at any time. This ensures access to all test data on any PC at any time.

Under the conditions of the pedagogical experiment, we tried to determine the quality of the measurement results. The experiment provides for the implementation of the test process three times and the fixation of the results with the correlation of the experimental factor. The results are presented in Table 1.

Table 1. Results of the test control of the coordination of movements of the lower limbs (n = 34)

Statistical parameters	Test tasks and measurement results (Number of times)					
	1st attempt		2st attempt		3st attempt	
	T	A	T	A	T	A
M	27.1	33.2	25.7	32.1	29.3	31.5
S	5.6	5.1	6.3	4.9	6.7	4.7
V (%)	35.2	19.7	36.1	20.8	30.9	19.2
	r_{tt}					
reliability	0.458	0.901	0.489	0.909	0.504	0.899
validity	0.231	0.612	0.251	0.607	0.297	0.633

*T – the traditional way, A – using the developed tool

First of all, it was determined in advance what we wanted to measure. Given that test theory emphasizes the absence of a fixed authenticity value that would allow a test to be considered acceptable (Chaabouni, et al., 2022), the obtained empirical data were used for the final comparative analysis.

According to the obtained numerical indicators, the numerical values of the test authenticity obtained by the traditional method of fixing the results by a specialist correspond to the value "low". Given that the lower limit of acceptable reliability values is usually chosen to be 0.7, the reliability coefficient of the test as an average measure of measurement accuracy, fixing the result in this way is unjustified due to significant measurement errors, which indicates that this method is time-consuming and inefficient.

According to the results of the calculations, the fixation of the results by the developed control device, the value of the reliability coefficient as internal consistency is > 0.9, which indicates "very high reliability". Taking into account such a reliability indicator, it can be argued that there is a lower probability of an error in the measurement of an individual result.

Given that reliability is required to achieve validity (Pribble, Black, Larson, & Larson, 2021), the results of the validity calculations showed that the correlation between the results of the test measures and the results of the assessment using the developed device corresponds to the level of "high" with a correlation coefficient greater than 0.6 The calculated coefficients of validity of the tests, where the recording of the results was carried out directly by the teacher, are within the "low" range.

Discussion

The relevance of our research is the urgent need to implement inclusion in institutions of higher education (Page, Anderson, & Charteris, 2021; Kuntjoro, Soegiyanto, Setijono, & Suhiharto, 2022). As hostilities on the territory of our country continue, a significant number of defenders return from the war with various injuries, and the number of students with disabilities will only increase in the future. Their full rehabilitation while studying in institutions of higher education is a guarantee of effective functioning, successful social reintegration, and full physical capacity (Blavt, Bodnar, Mykhalskyi, Gurtova, & Tsovkh, 2023).

Therefore, the conducted scientific research corresponds to the needs of modern times and aims to convey the current ideas of inclusion to students (Wolbring, & Lillywhite, 2021). We support scientific approaches (Kuntjoro, Soegiyanto, Setijono, & Suhiharto, 2022; Nanayakkara, 2022; Grenier, Patey, & Grenier-Burtis, 2022) that, from the point of view of fundamental ethics and respect for each student, the promotion of inclusive PE is positioned as a means improving the quality of life of students with disabilities, ensuring their inclusion and physical rehabilitation (Hutzler, & Levi, 2008; Pellerin, Wilson, & Haegele, 2022).

Our research is based on the need to monitor the level of development of basic physical qualities during inclusive PE, which is the basis for further planning of this process (Blavt, Iedynak, Pereverzieva, Holub, & Melnyk, 2023; Neto, Steenbergen, Wilson, Zamunér, & Tudella, 2020; Pellerin, Wilson, & Haegele, 2022).

Globalization and the advancement of new electronics increase the possibilities for objectivity and validity of test administration in PE (Gupta, 2021; Blavt, Iedynak, Pityn, Hluhov, Guska, Stadnyk, Zaikin, & Karatnyk, 2022). We will agree with our research that the use of the latest electronic technology in the data collection process eliminates the influence of the human factor on the results of the experiment (Gogoi, 2019; Hoenig, Amis, Edmonds, Morgan, Landerman, & Caves, 2018). This circumstance confirms the research data (Desrosiers, Rochette, & Corriveau, 2005; Chaabouni, Methnani, Al Hadabi, Al Busafi, Al Kitani, Al

Jadidi, Samozino, Moalla, & Gmada, 2022) regarding the inadmissibility of interpreting the materials obtained as a result of the experiment, which are obtained by tests with a low level of authenticity. The greater the influence of the human factor on the conduct of the experiment, the more difficult it is to judge to what extent the obtained results depend on the influence of external conditions and side factors (Rum et al., 2021; Mykytyuk, Blavt, Hnatchuk, Stechkevych, & Helzhynska, 2022).

The novelty of the implemented research is that for many years scientists have proposed foot-tapping testing to determine the capabilities of the neuromuscular system of the lower extremities in a medical context. Attempts were also made to use sensors to automate the used test, in particular inertial sensors (Djurić-Jovičić et al., 2018).

Until now, research on the use of this test in the practice of inclusive PE has not been conducted. The age-specific features of the development of these abilities are also taken into account, which improves again in youth (Ivashchenko, 2020). Given that sensorimotor indicators and general coordination abilities show a closer relationship in male individuals, male individuals were selected for the investigation (Davids, Button, & Bennett, 2008).

The practical value of the conducted research, as an important element of substantiating the significance of developments for the use of the obtained results in the process of inclusive PE, makes it possible to obtain an effect from the implementation, which will be another important step in its development.

Conclusions

Full-scale aggression on the part of Russia destroyed the normal course of social life and led to the urgent need to activate the institutions of inclusion of students with disabilities in higher education. For students with disabilities, given the limited opportunities for active activities due to the presence of deviations in their state of health, which complicate or make this process impossible, it is possible to ensure the rehabilitation process in order to restore lost functions by means of inclusive PE. The practical application of the inclusive PE device developed based on the latest electronics will allow us to optimize this process on a scientific basis to ensure its effectiveness.

The empirically determined indicators of test authenticity obtained during the experiment using the developed device, the digital values of which correspond to the "high level", ensure the individualization of control of the functional indicators of students with disabilities depending on the degree of disability, while at the same time creating an opportunity to develop their competencies. Our results showed that the obtained reliability coefficient values exceeding 0.9 indicate the high quality of the test. Therefore, the developed device is an acceptable method of controlling the level of coordination of movements of the lower limbs of students with disabilities.

Summing up, we can emphasize that the modern progress in inclusive PE, which is currently observed in Ukraine, allows us to hope that a high-quality inclusive space in higher education will be gradually and carefully created in our country, and its quality will meet the requirements of the continuous innovative process.

Conflicts of interest

No conflicts of interest exist.

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ТЕСТОВИЙ КОНТРОЛЬ ІНКЛЮЗИВНОГО ФІЗИЧНОГО ВИХОВАННЯ: ОЦІНЮВАННЯ З ВИКОРИСТАННЯМ НОВІТНЬОЇ ЕЛЕКТРОНІКИ

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

Реферат. Стаття: 7 с., 1 табл., 2 рис., 38 джерел.

Мета дослідження полягала у визначенні дієвості розробленого на основі новітньої електроніки пристрою для контролю координації рухів нижніх кінцівок студентів з інвалідністю.

Матеріал та методи. До дослідження було залучено 34 студенти з інвалідністю, які на момент початку експерименту мали функціональні розлади нижніх кінцівок внаслідок отриманих травм та отримали дозвіл лікаря на участь в експерименті. Дослідження проведено на теоретичному та емпіричному рівні, використано методи: аналізу, синтезу, систематизації, узагальнення, технічного моделювання, педагогічного тестування та математичної статистики.

Результати. У процесі дослідження використано пристрій, який розроблено в рамках проведеного дослідження. Пристрій складається з двох гумових килимків, у яких розмішують ємнісні сенсори наближення. Тестове завдання передбачає реєстрацію кількості торкань гумових килимків за 20 с. Інформація, яка надходить із сенсорів при виконанні студентом тестового завдання, а саме почергового торкання великим пальцем ноги гумових килимка, лінією інфрачервоного зв'язку надходить на мікроконтролер. У розробці використано високопродуктивний мікроконтролер ATMega 328P, який може підтримувати широкий спектр сенсорів та формує інформацію про час та частоту виконання рухів ногами. Сигнали торкання пальцями ніг студентом гумових килимків, отримані ємнісними сенсорами, обробляються мікроконтролером та відображаються на ПК через послідовне підключення та з застосування програмного забезпечення Arduino, що дозволяє зчитувати отриману інформацію виконання рухів. За умовами педагогічного експерименту ми намагались визначити якість результатів вимірювання. Згідно отриманим числовим показникам, числові значення тестової автентичності отримані традиційним способом фіксації результатів фахівцем, відповідають значенню «низький». Результати розрахунків валідності показали, що кореляція результатів тестових вимірів і результатів оцінювання з використанням розробленого пристрою була оптимальною з коефіцієнтом кореляції більшим за 0,6.

Висновки. Важливість високого рівня розвитку координації рухів нижніх кінцівок студентів з інвалідністю визначена необхідністю розвитку цієї якості задля забезпечення ефективності їхньої реабілітації в процесі інклюзивного ФВ. Аналіз отриманого матеріалу дозволяє стверджувати, що застосування у практиці інклюзивного ФВ розробленого на основі новітньої електроніки пристрою дозволить науково-обґрунтовано оптимізувати цей процес задля забезпечення його ефективності.

Ключові слова: студенти з інвалідністю, фізичне виховання, тестування, інклюзія, контроль, координація, нижні кінцівки.

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