



Determining the Quality of Measuring the Level of Lower Extremity Joint Movement in Inclusive Physical Education Using Electronic IT Resources

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Abstract

Objectives. The study aimed to investigate the quality characteristics of the tool developed based on electronic IT resources for measuring the level of movements in the joints of the lower limbs of students with disabilities caused by injuries.

Material and methods. The experimental study involved 32 first-year students who had sustained lower limb injuries as a result of the war and were in remission. The methods used included analysis, synthesis, systematization, generalization, technical modeling, pedagogical experiments, and mathematical statistics.

Results. A means of measuring movements in the joints of the lower limbs has been developed using electronic IT resources. The basis of the tool is a measuring line consisting of a printed circuit board on which is placed a design of capacitive sensors, a switching line, and a signal converter that measures the signal received by the sensors. The measurement results are transmitted to the controller and then to the PC via an interface implemented based on Bluetooth wireless technology. To implement the measuring tool, a controller is used, which has a board built on the synthesis of the Arduino electronic hardware platform and the Raspberry Pi minicomputer. The test results are displayed on the PC monitor screen. The determination of the qualitative characteristics of the test, in the case of recording the results of a tool developed on the basis of electronic IT resources for measuring the level of movements in the joints of the lower limbs of students with disabilities, established that the level of reliability of the test is above 0.90 (“excellent”) validity – from 0.6 (“high”). Empirical data collected directly from the experiment have a low level of reliability: qualitative indicators of reliability in the range are below 0.70 (“may have limited applicability”), validity – < 0.3 (“low validity”).

Conclusions. Developed based on electronic IT resources, the tool for measuring the level of movements in the joints of the lower limbs of students with disabilities due to limb injuries has significant advantages, such as the availability of functions, ease of use and efficiency. Ensuring high efficiency and objectivity of control contributes to performing control operations in real-time. By using assessment tools with a high level of reliability and validity, we ensure the detection of reliable changes in the state of the joints of the lower limbs of students with disabilities, thus eliminating the influence of errors in making managerial decisions in the planning process of their PE.

Keywords: students with disabilities, physical education, testing, inclusion, control, quality.

Introduction

As a result of the full-scale war and massive missile attacks that Russia has been waging on the territory of Ukraine

for more than two years in a row, the tendency to increase the number of students with disabilities in higher education institutions continues. At the moment, the first place among such a contingent of students are students who received a disability due to traumatic damage to their limbs. In particular, Ukrainian civilians receive such injuries as a result of shelling and bombing, and during hostilities, an extremely relevant mechanism of limb injuries today is an explosive injury.

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Today requires a new approach to adapting and restoring the health status of students with disabilities in the environment of higher education – modern technological solutions and an integrated approach (Blavt, Bodnar, Mykhalskyi, Gurtova, & Tsovk, 2023). Solving this issue in the learning process takes place in the process of implementing inclusive physical education (PE).

Educating students with disabilities in institutions of higher education poses a number of challenges that require comprehensive solutions (Grenier, Patey, & Grenier-Burtis, 2022). The view of well-known authorities in this field is convincing (Kuntjoro, Soegiyanto, Setijono, & Suharto, 2022; Page, Anderson, & Charteris, 2021) that the indicator of modern quality education is innovative activity. Scientific investigations (Varga, & Révész, 2023; Blavt, Chaplinskyi, Prozar, Pityn, Helzhynska, Dmytruk, Hrebik, & Kovalchuk, 2023; Gupta, 2021) focus on the fact that, in accordance with the modern innovative progress, this involves the introduction of the latest achievements of technological development.

The problem of the quality of inclusive PE in connection with the constant increase of students with disabilities is in the epicenter of researchers' attention (Blavt, Iedynak, Pereverzieva, Holub, & Melnyk, 2023; Pellerin, Wilson, & Haegele, 2022). In this context, they talk about the quality of physical education (Pocock, & Miyahara, 2018), its control (Blavt, & Gurtova, 2023; Mykytyuk, Blavt, Hnatchuk, Stechkevych, & Helzhynska, 2022), verification (Rekaa, Hanisch, & Ytterhus, 2019), evaluation (Lieberman, & Houston-Wilson, 2017).

Certain works, which are focused on the issues of restoring the health of students with disabilities, see the solution to this issue in the use of the basics of inclusive pedagogy, innovative practices of inclusive PE and integration into this process, modern information and communication (IT) resources (Gogoi, 2019; Qi, & Ha, 2012; Blavt, Chaplinskyi, Prozar, Pityn, Helzhynska, Dmytruk, Hrebik, & Kovalchuk, 2023). On the other hand, according to (Bezell, Grindstaff, Sauer, Magrum, MIngersoll, & Hertel, 2012; Cimbiz, & Bayazit, 2004; Doherty, Delahunt, Caulfield, Hertel, Ryan, & Bleakley, 2014), the complex recovery needs of traumatic limb injury include ongoing assessment of the process of strengthening lost functions.

In view of the continuation of the armed confrontation with the aggressor and the prevalence of injuries associated with the consequences of military actions, the issue of restoring lost functions due to limb injuries in students with disabilities during their studies in higher education institutions is now gaining special importance.

Purpose of the research in the study of qualitative characteristics of the quality of the tool developed on the basis of electronic IT resources for measuring the level of movements in the joints of the lower limbs of students with disabilities due to injuries.

Materials and Methods

Study Participants

32 students with disabilities in the 1st year of study from Lviv Polytechnic National University, Kamianets-Podilskyyi Ivan Ohiienko National University and Lutsk National

Technical University took part in the experimental study. The studied sample for the implementation of the research plan was formed randomly without taking into account the gender factor. It included students who received injuries to their lower limbs as a result of the war and were in remission.

Students with disabilities involved in the study underwent a thorough medical examination and received a doctor's permission to participate in the experiment. Positive dynamics of the functional state were established in all study participants. Consent to participate in the experiment was obtained from all students with disabilities who made up the studied sample.

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 Methods

The research has a multi-method applied nature and is implemented at the theoretical and empirical level. The procedure for solving the research task involved the use of a systematic approach in the search for research methods as an integrated set of tools for its implementation (Ivashchenko, 2020).

General scientific methods of theoretical research are used: analysis, synthesis, abstraction, generalization. At the empirical level, the method of technical modeling (to create a means of control) and a pedagogical experiment was used.

During the pedagogical experiment, testing was carried out. The implementation of the research plan involved the selection of the appropriate purpose of the test exercise. The Weight Bearing Lunge Test was chosen by us due to its ease of execution and the possibility of repeated reproduction.

According to the information (Weight-bearing lunge test), this test is considered simple for measuring the range of dorsiflexion of the ankle joint under load, which is a key component of gait in healthy ankles and in diseases of the musculoskeletal system (is a simple method of measuring weight bearing ankle dorsiflexion range, a key component of gait, in healthy ankles and a range of musculoskeletal conditions)

The Weight-bearing lunge test (WBLT) is used to assess the dorsiflexion range of movement at the ankle joint. (Powden, Hoch, Hoch, 2015; Konor, Morton, Eckerson, Grindstaff, 2012)

Test Procedure

This test needs to be done against a wall. A standard tape measure (cm) is necessary. Students are asked to place their feet in such a way that an imaginary line drawn through the heel and big toe is aligned on the tape measure on the floor. Furthermore, a vertical line is drawn on the wall in line with the tape measure. Students are instructed to lunge forward until their knee touches the wall (vertical line). The heel is required to remain in contact with the floor at all times. The foot is moved away from the wall to the point where the knee can only make slight contact with the wall, while the heel remains in contact with the floor. This puts the ankle

joint in maximal dorsiflexion. The leg not being tested can rest on the floor and students are allowed to hold onto the wall for support. The maximum distance from the wall to the tip of the big toe is recorded. The distance is measured in centimeters (cm) with each centimeter corresponding to approximately 3.6° of ankle dorsiflexion (Weight-bearing lunge test).

Research Organization

The research was carried out within the course of inclusive PE for three months. The testing was carried out at the beginning of the month, the students of the studied sample performed the tests three times with each limb. In the presence of a pain syndrome, students were not allowed to take the test. Clear instructions for performing the test exercise were provided, after which there was an opportunity to try.

The experimental factor consisted of fixing the results of the test exercise since the degree of reliability can be affected by the subjective approach when evaluating the test results. In one case, the results were recorded by the teacher, in the other - with the use of a tool developed for measurement, the evaluation of the test was carried out without subjective judgment. It should be noted that the test results were recorded simultaneously by two alternative measurement methods during each test. It is taken into account that the presumption of obtaining data may be imperfect in the presence of influence. To form research conclusions, the average value of the generated data was used.

Statistical Analysis

Determining the quality characteristics of the test involves establishing the numerical values of reliability and validity. As the technical properties of the test, the quality characteristics indicate the quality and usefulness of the test. The determination of these parameters allows establishing the compliance of the test with formal criteria that determine its quality and suitability for use in practice with a certain contingent of subjects.

The study takes into account that the reliability of a test limits its validity, and therefore a test that is not reliable cannot be valid. Quality control of the tests was carried out by establishing the strength of the correlation, which is determined by the value of the correlation coefficient. The coefficient is expressed as a Pearson correlation, a measure of linear correlation between two sets of data that ranges from +1.00 to -1.00 (Turney, 2022). The measure of correlation has become the basis of judgments about the validity of the test: a correlation value of less than 0.2 or 0.3 provides empirical evidence that the test is unsuitable for use in practical work (Eisinga, Te Grotenhuis, Pelzer, 2012).

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

Results

Determining the flexibility of the ankle joint in the process of recovery after a traumatic injury to a limb is considered an opportunity to control the process of recovery after a traumatic injury to a limb, which is accompanied by

limitation of mobility and range of motion, possibly caused by cicatricial tightening of the skin, tendons, pain reflex, pathological changes in the muscular system (as excessive foot pronation or plantar fascia), etc. (Dai, Herman, Liu, Garrett, & Yu, 2012).

In our study, we were guided by the information that a decrease in the range of motion of dorsiflexion of the ankle joint has been identified as a risk factor for lower limb injuries during physical activity (Wahlstedt, & Rasmussen-Barr, 2014). According to available data (Hall, & Docherty, 2017), a total lunge distance of less than 10 cm or a side-to-side discrepancy of more than 2 cm is associated with a risk of lower extremity injuries such as sprained ankle ligaments or possible tibial fracture. In addition, it has been proven that the efficiency of the walking function is provided by the appropriate range of motion in the ankle dorsiflexion (O'Shea, & Grafton, 2013).

As noted, the absence of adequate amplitude in the ankle indicates the presence of pathological changes (Lin, Moseley, Robert, Herbert, & Refshauge, 2009). Therefore, permanent control in the process of restoring the functions of the lower limbs is the basis of this process.

Our scientific search was conditioned by the fact that, according to empirical sources, ankle dorsiflexion testing is traditionally performed using a goniometer (Cosby, & Hertel, 2011) or an inclinometer (Bezell, Grindstaff, Sauer, Magrum, Ingersoll, & Hertel, 2012) or a tape measure (Matthew, Hoch & McKeon, 2011). However, none of these methods ensures the elimination of the influence of the human factor. In addition, fixing the result using such means is technically difficult.

The actual material collected and analyzed proved the possibility of developing a means of measuring movements in the joints of the lower limbs based on electronic IT resources. The design solution of the tool involves the use of a measuring line, which is built using the concept of capacitive sensors (Mykytyuk, Kremer, Ivakh, Diskovskiy, & Khomyak, 2021). The basis of the capacitive measuring line is a printed circuit board that integrates capacitive sensors, a switching line, and a signal converter (Mykytyuk, Barylo, Kremer, Kachurak, & Shymchyshyn, 2024).

The signal is measured by a signal converter, and the measurement results are transferred to the controller by an interface based on wireless Bluetooth technology. The signal converter provides further signal conversion and processing of digital data and RF radio frequency transmission to a personal computer (PC). Processing of the received data and their visualization is carried out by the corresponding software for the implementation of the measurement, which is developed in the Arduino IDE environment.

To implement the measuring tool, a controller is used, which has a board built on the synthesis of the Arduino electronic hardware platform and the Raspberry Pi minicomputer. The controller in the developed control tool performs the following functions: it automatically manages the control process, in case of non-compliance with the requirements, signals and stops this process, receives information recorded by sensors, processes it, and transmits it to a PC.

All information is displayed on the PC monitor in digital and graphic form. The PC implements recording and storage of control data and statistical analysis of data that are available to the user as needed.

Table 1. Quality level of the Weight Bearing Lunge Test for students with disabilities due to injuries (n=32)*

rtt	T	R	T	R	T	R	T	R
reliability	0.616	0.908	0.640	0.901	0.589	0.897	0.611	0.917
validity	0.201	0.603	0.207	0.597	0.176	0.612	0.233	0.591

* Note: T – recorded by the teacher, R – recorded using a measuring ruler

The developed measuring tool for the implementation of the Weight-Bearing Lunge Test is used as follows. A capacitive measuring ruler is placed on the wall and the floor. The student takes the starting position for the test exercise and moves his foot on the ruler. Next, the student lunges forward until his knee touches the wall, where a capacitive measuring ruler is also placed along the vertical line. At the moment of touching the ruler placed vertically on the wall with the knee, the maximum distance from the wall to the tip of the big toe is fixed with the ruler placed horizontally.

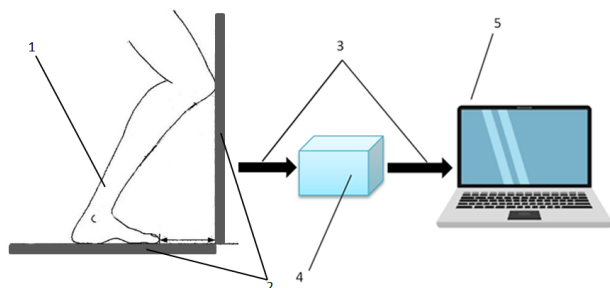


Fig. 1. Scheme of the developed on the basis of electronic IT resources for measuring the level of movements in the joints of the lower limbs (1 – student, 2 – capacitive measuring ruler with printed circuit board, 3 – infrared communication lines, 4 – controller, 5 – PC)

Further, our study consisted in presenting the test results, which were recorded using a measuring ruler and directly by the teacher (Table 1).

The conducted research established that the use of different means of fixing the test results leads to a significant difference in the test results. Taking into account the fact that the collection of empirical data of the experiment directly depends on the human factor, in particular on professional experience, the results obtained in this way have a low level of quality: qualitative indicators of reliability within the limits – below 0.70 (“may have limited applicability”), validity – < 0.3 (“low validity”). Therefore, we have grounds for the conclusion that such control cannot be an objective basis for planning the educational process.

By determining the quality characteristics of the test, in the case of fixing the results of a tool developed based on electronic IT resources for measuring the level of movements in the joints of the lower limbs of students with disabilities due to injuries of the limbs, it was established that the level of reliability of the test is above 0.90, validity – from 0.6. Such numerical values of reliability correspond, according to the rating scales, to the level of “excellent”, validity – to “low validity of the test”.

Discussion

In Ukraine, persons with disabilities have access to higher education and the conditions for obtaining it. The

conducted study expands the information (Blavt, Bodnar, Mykhalskyi, Gurtova, & Tsovk, 2023; Doherty, Delahunt, Caulfield, Hertel, Ryan, & Bleakley, 2014) on solving the problem of normalization of the physical condition of students with disabilities who were injured as a result of war, by eliminating existing health problems during training.

Our scientific intelligence is conditioned by the fact that the challenges that have arisen before the education system of Ukraine are connected with the long-term conduct of hostilities in connection with the military aggression of the Russian Federation. Our study extends the body of research on inclusive PE in educational settings (Grenier, Patey, & Grenier-Burtis, 2022; Pellerin, Wilson, & Haegele, 2022) as a means of restoring function lost due to injury. Inclusion in regular PE classes of students with disabilities requires adaptation of strategies for this process and its assessment to their individual needs (Pocock & Miyahara, 2018; Blavt & Gurtova, 2023).

We support scientific approaches (Page, Anderson, & Charteris, 2021; Gupta, 2021; Blavt, Chaplinskyi, Prozar, Pityn, Helzhynska, Dmytruk, Hrebik, & Kovalchuk, 2023) that meeting today’s demands in the field of inclusive PE requires innovative solutions with using modern technological resources.

The work presents a development that meets the challenges of modernity in the implementation of monitoring procedures since when restoring functions are lost as a result of an injury when it is extremely important to start recovery quickly, monitoring must be informative and fast. In our study, we were guided by the fact that ankle dorsiflexion range of motion is often emphasized (Powden, Hoch, & Hoch, 2015; Beynon, Le May, & Theroux, 2022) in rehabilitation of lower extremity injuries. To date, there is a certain list of scientific studies where The Weight Bearing Lunge Test has been used to test completely healthy individuals (Konor, Morton, Eckerson, & Grindstaff, 2012; O’Shea, & Grafton, 2013) and athletes (Cady, De Ste Croix, & Deighan, 2021) and as a universal assessment test (Howe, Bampouras, North, & Waldron, 2020).

In our study, the sample was formed from persons who have disabilities due to injuries of the lower limbs, and therefore, it expands the range of previous studies in a certain direction. The direction of the research was justified by the fact that the validity of the test is established in relation to specific reference groups (target group) of persons with certain common characteristics.

Conclusions

Russian aggression against Ukraine has caused a serious increase in the number of students with disabilities who have been injured as a result of the war. Strategic orientations for the recovery of the health status of students with disabilities, who received injuries of the lower extremities as a result of

the war, are considered in the context of the possibilities of inclusive PE and the integration of the latest technologies into the control of this process.

Developed based on electronic IT resources, the tool for measuring the level of movements in the joints of the lower limbs of students with disabilities due to limb injuries has significant advantages, such as the availability of functions, ease of use, and efficiency. Ensuring high efficiency and objectivity of control performs control operations in real-time. Moreover, this tool is non-invasive, inexpensive, and does not emit radiation.

According to the results of the analysis of the qualitative characteristics of the qualitative characteristics of the means of measuring the level of movements in the joints of the lower limbs of students with disabilities developed based on electronic IT resources, it was established that the numerical values of the reliability and validity indicators reached a high level according to the rating scales. Using evaluation tools with a high level of quality, we ensure the objectivity of control and elimination of the influence of errors in making management decisions in the planning of the PE process.

Using a test to measure the level of movement in the joints of the lower limbs of students with disabilities, when the results are recorded by the teacher, is not justified due to large measurement errors. A low level of reliability is not the basis for informed decisions and the understanding that the test results are not an artifact of the instrument.

Conflicts of interest

No conflicts of interest exist.

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Визначення добротності розробленого на основі ІТ-ресурсів засобу вимірювання рівня рухів у суглобах нижніх кінцівок у інклюзивному фізичному вихованні

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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 дослідженні якісних характеристик добротності розробленого на основі електронних ІТ-ресурсів засобу вимірювання рівня рухів у суглобах нижніх кінцівок здобувачів вищої освіти з інвалідністю внаслідок травм.

Матеріал та методи. У дослідженні прийняли участь 32 здобувачів вищої освіти І курсу навчання, які отримали травми нижніх кінцівок внаслідок війни і знаходяться у стані ремісії. Використано методи: аналізу, синтезу, систематизації, узагальнення, технічного моделювання, педагогічного експерименту та математичної статистики.

Результати. Розроблено на основі електронних ІТ-ресурсів засіб вимірювання рухів у суглобах нижніх кінцівок. Основою засобу є вимірювальна лінійка, яка складається з друкованої плати, на якій розмішено конструкція з емнісних сенсорів, лінії комутації та сигнального перетворювача, який вимірює сигнал, отриманий сенсорами. Передачу результатів вимірювання на контролер, а далі на ПК, – інтерфейсом, реалізовано на основі безпроводної Bluetooth технології. Для реалізації засобу вимірювання, використано контролер, який має плату, побудовану на синтезі електронної апаратної платформи Arduino и мінікомп'ютера Raspberry Pi. Результати тестування представляються на екрані монітора ПК. Визначенням якісних характеристик добротності тесту, у разі фіксації результатів розробленим на основі електронних ІТ-ресурсів засобу вимірювання рівня рухів у суглобах нижніх кінцівок студентів з інвалідністю, встановлено, що рівень надійності тесту становить вище 0,90 («відмінна») валідності – від 0,6 («висока»). Емпіричні дані експерименту зібрані прямим способом володіють низьким рівнем добротності: якісні показники надійності у межах – нижче 0,70 («має обмежене застосування»), валідності – < 0,3 («низька валідність»).

Висновки. Розроблений на основі електронних ІТ-ресурсів засобу вимірювання рівня рухів у суглобах нижніх кінцівок студентів з інвалідністю внаслідок травм кінцівок володіє значним перевагами, як от доступність функцій, простота у використанні й ефективність. Забезпечуючи високу ефективність та об'єктивність контролю, здійснює виконання контролювальних операцій у режимі реального часу. Використовуючи інструменти оцінювання з високим рівнем добротності, забезпечуємо виявлення достовірно змін у стані суглобів нижніх кінцівок студентів з інвалідністю та усунення впливу помилок у прийнятті керівних рішень планування процесу їхнього ФВ.

Ключові слова: здобувачі вищої освіти з інвалідністю, фізичне виховання, тестування, інклюзія, контроль, добротність.

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