

FEATURES OF POSTURAL STABILITY IN PHYSICALLY HEALTHY CHILDREN WITH SPECIAL EDUCATIONAL NEEDS ACCORDING TO THE RESULTS OF CERTAIN INSTRUMENTAL FIXATION

Shi Lei¹<https://orcid.org/0009-0008-7286-3397>Yaroslav Kurivskyi²<https://orcid.org/0000-0003-4001-7803>Tymur Matsiyevych³<https://orcid.org/0009-0004-2211-6773>¹ College of Competitive Sports, Shandong Sport University, China²⁻³ Kamianets-Podilskyi Ivan Ohienko National University, Ukraine

кореспондент-автор – Ya. Kurivskyi: opndf22.kurivskyi@kpnpu.edu.ua

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The article discusses data on the validity and reliability of the developed software and hardware complex for recording the results of 14-17-year-old students from the healthy population and those with special educational needs in the postural stability test. *The aim of the study* was to experimentally determine the compliance of the software and hardware complex, developed based on the latest electronics, with metrological requirements for recording the results of adolescents and young people from different nosological groups in the postural stability test. *Materials and methods.* The study involved 34 girls and 34 boys with special educational needs and 24 girls and 22 boys from the healthy population; their ages ranged from 14.5±0.4 to 15.1±0.3 years. The developed complex was used to record results in BESS, which enables the assessment of postural stability development in different population groups. The reliability and criterion validity of the developed complex and the traditional method of recording test results were determined. The data of girls and boys from the healthy population, as well as those with special educational needs due to diseases of the cardiovascular and nervous systems, were analyzed separately. *Results.* The experimental data showed a discrepancy in the values of reliability and validity when recording results in BESS traditionally and using the developed complex. Thus, in the first case, the reliability of girls and boys from the healthy population was average (rtt from 0.355 to 0.611 and from 0.342 to 0.617, respectively), and validity was predominantly low (rtt from 0.182 to 0.343, from 0.182 to 0.331). The use of the developed complex ensured a high level of reliability (in girls, it was characterized by rtt from 0.901 to 0.951, in boys, from 0.902 to 0.954) and average validity (rtt from 0.591 to 0.687 and from 0.601 to 0.687). Similar levels, with the exception of correlation coefficients, were observed for the reliability and validity of the results in girls with cardiovascular and nervous system diseases, as well as in boys. *Conclusions.* The use of girls aged 14-17 from a healthy population and with special educational needs due to diseases of the cardiovascular and nervous systems, as well as boys, was noted with practically the same values of validity and reliability. However, in all cases, the developed complex for recording results in BESS prevailed over the traditional (visual) method. Objective, accurate, and reliable information obtained from the developed complex can significantly increase the effectiveness of personal physical activity programs for improving postural stability in adolescents and young people.

Keywords: adolescents, young people, postural stability, testing, outcome assessment, reliability, validity.

Shi Lei, Ярослав Курівський, Тімур Мацієвич. Особливості поструральної стабільності у фізично здорових дітей та з особливими освітніми потребами за результатами спеціальної інструментальної фіксації

Анотація. У статті розглянуто дані про валідність та надійність розробленого software and hardware complex для фіксації результатів учнів 14-17 років здорової популяції та з особливими освітніми потребами у тесті на поструральну стабільність. *Мета дослідження* полягала в експериментальному визначенні відповідності метрологічним вимогам програмно-апаратного комплексу, розробленого на основі новітньої електроніки для фіксації результатів підлітків і молоді різних нозологічних груп у тесті на поструральну стабільність. *Матеріал та методи.* У дослідженні взяли участь 34 дівчинки, 34 хлопчики з особливими освітніми потребами та 24 дівчинки, 22 хлопчики здорової популяції; вік усіх був у межах від 14,5±0,4 до 15,1±0,3 років. Розроблений комплекс використовували для фіксації результатів у BESS, який дозволяє оцінювати у різних групах населення стан розвитку поструральної стабільності. Визначали надійність та критеріальну валідність розробленого комплексу та традиційного способу фіксації результатів у тесті. Аналізували окремо дані дівчаток і хлопчиків здорової популяції, а також із особливими освітніми потребами внаслідок захворювань серцево-судинної та нервової систем. *Результати.* Дані експерименту свідчили про розбіжність значень надійності, валідності у випадку фіксації результатів у BESS традиційно та з використанням розробленого комплексу. Так у першому випадку в дівчаток і хлопчиків зі здорової популяції надійність була середньою (rtt відповідно від 0.355 до 0.611, від 0.342 до 0.617), валідність – переважно низькою (rtt від 0.182 до 0.343, від 0.182 до 0.331). Використання розробленого комплексу забезпечило високий рівень надійності (у дівчаток її характеризували rtt від 0.901 до 0.951, у хлопчиків – від 0.902 до 0.954) та середній – валідності (rtt від 0.591 до 0.687 та від 0.601 до 0.687). Аналогічними рівнями, за винятком значень коефіцієнтів кореляції, відзначалася надійність і валідність фіксації результатів у дівчаток із захворюваннями серцево-судинної та нервової систем, а також хлопчиків. *Висновки.* Використання дівчатками 14-17 років зі здорової популяції та з особливими освітніми потребами внаслідок захворювань серцево-судинної і нервової систем, так само як і хлопчиками, відзначалося практично однаковими значеннями валідності й надійності. Але в усіх випадках розроблений комплекс фіксації результатів у BESS переважав традиційний (візуальний) спосіб. Об'єктивна, точна і надійна інформація, отримана від розробленого комплексу може суттєво підвищити дієвість персональних програм фізичної активності з поліпшення у підлітків і молоді поструральної стабільності.

Keywords: підлітки, молодь, поструральна стабільність, тестування, оцінювання результату, надійність, валідність.

Introduction

Postural stability is currently considered to be the body's ability to maintain and effectively counteract disturbances in balance and stability through the coordinated activity of the somatosensory (nerve-muscle) system, vestibular apparatus, vision, and proprioception [3; 23]. Other information [6; 17] allows us to characterize this human ability in more detail—this concept is used to describe how the central nervous system analyzes sensory information from other systems in order to produce an adequate motor response to maintain a controlled upright position. The main sensory systems involved in postural stability are the visual, vestibular, and somatosensory systems, and the key functional goals of postural control are postural orientation and balance. Postural orientation is responsible for controlling the state and tone of the body in relation to gravity, the supporting surface, the visual environment, and internal landmarks. Postural balance is the coordination of sensorimotor strategies to stabilize the body's center of mass during both involuntary and external stimuli [6; 9; 36].

Postural stability is studied primarily by specialists in physical education, children's sports, and physical therapy. The main reason for the increased attention to it is that this ability is very important in ensuring the normal functioning of an individual, regardless of age [5; 20; 37; 43]. First of all, this concerns the ability of an individual to perform various static and dynamic movements (sitting, standing, kneeling, moving on all fours, crawling, walking, running) with the ability to contract the appropriate muscles to maintain balance. It also refers to the ability to make small corrections in response to changes in position and movement without using compensatory movements [16; 26].

From the perspective of physical education theory, postural stability is a type of coordination, specifically the ability to maintain balance [1, p. 111]. At the same time, performing postural stability exercises by children aged 10-12 contributes to improving the results in the manifestation of other motor qualities, in particular speed, various types of general and a special type of coordination as balance [7].

From the perspective of physical therapy, postural stability is considered primarily in relation to brain function after a series of diseases. These include stroke [2], Parkinson's disease, multiple sclerosis, traumatic brain injury, military injuries, and sports-related concussions [10].

In this regard, the problem of recording the results of postural stability in children belonging to different nosological groups becomes relevant. To a large extent,

this concerns the tools that can be used to determine postural stability relatively quickly, reliably, and, most importantly, accurately [11; 44]. In particular, children are offered [22] to use the "KörperKoordinationstest für Kinder" test. According to other information [20], the BESS (balance error scoring system) test is universal, i.e., suitable for both children and adults. In addition, its other advantages include the speed of obtaining results, relative ease of use, and the use of inexpensive tools. However, there are also some drawbacks, one of the main ones being the recording of results [11; 27]. In particular, the test involves counting the errors made by the child in each of the three positions provided for in the test. Errors are determined by visual fixation and comparison with the test requirements. Therefore, there is a possibility of making a mistake when recording the result, since such an assessment is based on the subjective opinion of the person performing it [12; 21]. To be more specific, BESS involves recording the maintenance of correct body position when performing three different stances on each of two surfaces (hard and soft). At the same time, it is necessary to comply with the requirements specified in the protocol, in particular, the position of the arms and legs. The following are considered errors: moving the arms away from the iliac crests, opening the eyes, stumbling or falling, moving or bending the hips more than 30°, lifting the front of the foot or heel above the surface, or staying in a position other than the specified one for more than 5 seconds. In addition, there is a possibility of error when monitoring the time the child maintains a stable body position.

High-tech capabilities of the latest electronics can contribute to the successful solution of this problem [9]. To a certain extent, this is confirmed by empirical data on the effectiveness of electronic technologies in monitoring the results of physical activity [19]. In addition, the use of such technologies allows: correct and effective assessment of the results of various physical activity tasks; quick access to all information obtained during testing; and the solution of some other, but equally important tasks [18; 41].

Taking into account all of the above information, the need for research aimed at verifying the effectiveness of recording BESS results using an instrumental method was noted. That is, we are talking about a complex for determining the state of development of postural stability in children and young people [4]. The metrological effectiveness of its use in the practice of inclusive physical education was established by a special study [11]. With regard to adolescents with special educational needs and those who do not need them due to normal development, information on the state of postural stability development

in the latter is scarce [30], and in the former, it is completely absent.

Purpose of the research – to experimentally determine the compliance with metrological requirements of the software and hardware complex developed on the basis of the latest electronics for recording the results of adolescents and young people of different nosological groups in the postural stability test.

Materials and methods

Research methods. The methods chosen for the study corresponded to its purpose and objectives. At the theoretical level, these were methods of analysis and systematization. With their help, various sources of information were processed. At the empirical level, testing and methods of mathematical statistics were used. A systematic approach was used to organize the study. This involved several stages. In the first stage, we obtained as much complete, objective, and reliable information as possible about the state of the problem under study. In the second stage, we compared the test results obtained in each attempt and in the formed nosological group of adolescent children. The third stage involved summarizing the results of the comparison of the empirical data obtained. During the fourth stage, conclusions were drawn and the information obtained by us and other researchers was compared to confirm or refute the conclusions and assumptions made.

Study participants. Considering that the degree of authenticity of the test is directly related to the homogeneity of the sample, important characteristics of the girls and boys who participated in the study were taken into account when forming the sample. A total of 34 girls and 34 boys with special educational needs (SEN samples) were involved, of whom 20 and 22 had cardiovascular diseases, 14 and 12 had nervous system diseases, respectively. The sample of children without developmental abnormalities (main sample – MS) included 24 girls and 22 boys. The age of all children who participated in the study ranged from 14.5 ± 0.4 to 15.1 ± 0.3 years. The base for the study of SEN participants was a school in China called “BBSG” (Bilingual Benenden School Guangzhou). The base for the study of SEN participants was a sanatorium-resort facility in Ukraine, where children with certain diseases received the necessary services. All parents gave their consent for their children to participate in the study. 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”.

Test procedure. Testing took place in the morning, using the BESS test, which is most commonly used by foreign researchers. This test consists of a combination of three stances. The positions are as follows: in the double leg stance, in the single leg stance position, in the tandem stance (fig. 1).

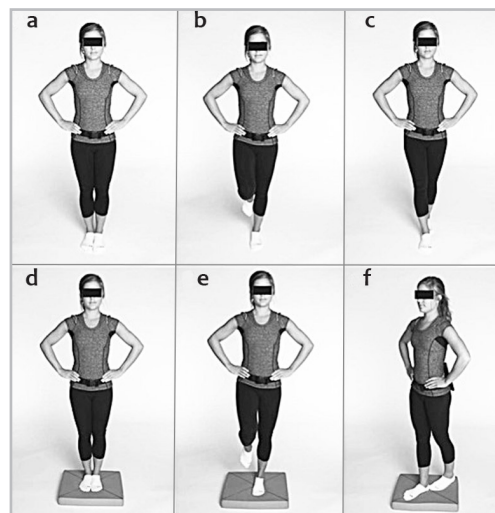


Fig. 1 Conditions for performing the stances included in the BESS on a hard surface ((a)–(c)) and a foam surface ((d)–(f)). Figure reprinted with permission from Ozginga et al. [30]

Each stance is performed with eyes closed for 20 seconds on different support surfaces, namely on the floor (hard surface) and on a foam mat (soft surface, dimensions – 100x100 mm or more) [20; 30]. If the test conditions are violated, points are awarded, in particular for opening the eyes, removing the hands from the hips, moving or bending the hip more than 30°, lifting the front of the foot or heel above the surface, or losing balance (stepping to one side, stumbling, falling, etc.). Therefore, a higher total score indicates a worse test result. The maximum number of errors for each stance is 10.

Research organization. The study was conducted in accordance with the principles of empirical research ethics. It was aimed at obtaining empirical facts, primarily the average result in three attempts to perform each stance. At the same time, the best result was taken into account. The necessary information was collected using two methods of recording results in BESS, namely, using the software and hardware complex (SHC) developed by us and traditionally (T). It was important to create the same conditions for all participants: before the start of testing, all children received the necessary instructions; the experimenter was thoroughly familiar with the testing methodology, namely, had the necessary skills to organize and implement this procedure and record the results.

Statistical analysis. The test results were processed using appropriate methods of mathematical statistics. For this purpose, SPSS version 22.0 (IBM Corporation) was

used to determine the arithmetic mean (Mean), standard deviation of the mean (SD), median (Me), and coefficient of variation (V). In addition, quantitative characteristics were determined to establish the reliability of the methods we used to record results in BESS and their criterion validity. In this case, taking into account the information provided by researchers [40], correlation analysis (r) was applied.

Results

The method we developed for recording results in BESS allows, in our opinion, for a more accurate and qualitative determination of the level of development of postural stability in adolescents. It was based on scientific knowledge about human balance control, namely, that it is a combined process involving somatosensory, visual, and vestibular systems [23]. Balance is considered within the framework of such a human motor quality as coordination and means the ability to maintain the body's center of gravity on a supporting surface [34].

Taking this into account, in order to record the results in BESS more accurately, a method was developed that involves the use of SHC (hereinafter referred to as the SHC method), which combines hardware and data processing algorithms. This complex made it possible to accurately analyze data, eliminate the subjective influence of the human factor on the result, and also allowed it to function in energy-saving mode. The basis of the software and hardware complex for recording BESS results is Force Sensitive Resistor piezoelectric pressure sensors, which are placed in a soft mat used during the test. The main function of the Force Sensitive Resistor is to continuously monitor body weight distribution to record any deviation, including displacement of the center of gravity and loss of balance, even minimal [33]. Another advantage of Force Sensitive Resistor sensors is their simplicity of operation, low power consumption, and ability to run on batteries due to their power consumption of only 5 volts.

To integrate several sensors into a single system, we used Arduino Mega, the latest version of the top-of-the-line microcontroller board. Thanks to its large number of input ports, it acts as a hub that collects data obtained by reading signals from all connected sensors [4]. Arduino Mega consists of a microcontroller with input/output elements and a Processing/Wiring environment that identifies changes in weight load after initial processing of signals from the Force Sensitive Resistor and System in Package (SiP). The latter is represented by a motion module (an improved version of MPU-9250) – another important component of the developed software and hardware complex. The module integrates a Digital Motion Processor (DMP) and a MotionFusion system for

detecting activity and calibration along 9 axes using a gyroscope and accelerometer. MotionFusion algorithms process information from all sensors and generate a complete set of data on any movements of the child's body that occur during the test. In other words, it tracks body tilts and angular displacements in different planes (forward-backward, left-right). The module is placed on the child's belt or shoes.

The SHC works as follows: while the child is performing the BESS, signals from the Force Sensitive Resistor sensors are sent to the Processing/Wiring hardware computing platform of the Arduino Mega microcontroller (fig. 2).

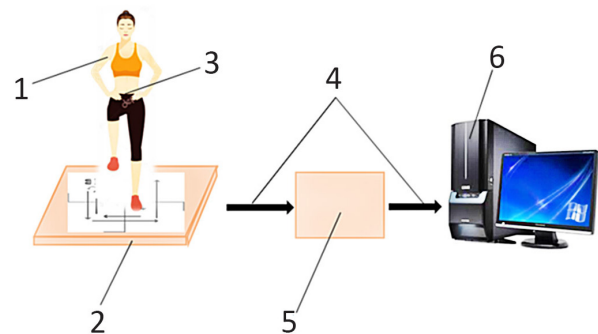


Fig. 2 Diagram of BESS results recording using a developed software and hardware complex for assessing the development of postural stability in children. Figure reprinted with permission from Blavt et al. [11]

Note. Labeled: 1 – child performing the test, 2 – Force Sensitive Resistor, 3 – MPU-9250 motion sensor module, 4 – infrared communication lines, 5 – Arduino Mega microcontroller hardware computing platform, 6 – personal computer (smartphone)

Signals from the DMP are also sent to it. Wireless modules, such as HC-05 (Bluetooth) or ESP32 (Wi-Fi), are used to transmit data in real time to a personal computer or smartphone screen. In conducting the experiment, we sought to determine the quality of the BESS results obtained using the T-method and the SHC (hereinafter referred to as the SHC-method). When analyzing the data obtained, we took into account information from test theory about the criterion validity and reliability of research tools [14].

MS samples. After recording the results for girls using each of the two methods, we found that the T-method in each case (three stands) was characterized by a low level of validity. Thus, performing stands on a hard surface provided the following correlation coefficient (r_{tt}) values: stand on two legs – 0.321, on one leg – 0.211, tandem – 0.343. A similar level was noted for the T-method of recording results in the same girls, but when performing on a soft surface. Thus, the r_{tt} values were: standing on two legs – 0.231, on one leg – 0.182, tandem stance – 0.198 (Table 1). In other words, all the values given were within the range of 0 to 0.3.

Table 1 – Sample Demographics (OB – girls, n = 24)

Statistical parameters	BESS tasks and measurement results in the firm surface (number of errors)					
	Double-legged stance		Single-legged stance		Tandem stance	
	T	SHC	T	SHC	T	SHC
Mean	0.28	0.10	3.82	2.23	1.02	0.31
± SD	0.29	0.14	2.18	1.03	0.95	0.22
Median	0	0	4.0	2.0	1.0	0
V (%)	23.24	9.31	27.90	13.81	32.91	18.78
rtt						
reliability	0.671	0.809	0.355	0.912	0.511	0.901
validity	0.321	0.591	0.211	0.657	0.343	0.684
BESS tasks and measurement results in the foam surface (number of errors)						
Mean	0.71	0.11	7.91	3.55	4.08	1.53
± SD	0.52	0.16	2.51	1.27	1.79	0.27
Median	1.0	0	8.0	3.5	4.0	1.5
V (%)	28.11	12.15	31.74	10.11	31.22	12.14
rtt						
reliability	0.466	0.915	0.411	0.951	0.427	0.918
validity	0.231	0.618	0.182	0.687	0.198	0.667

They showed a low correlation between the studied indicators, i.e., a low level of validity of the T-method of recording results in BESS [42]. The use of the SHC-method provided significantly higher validity than the T-method. Thus, when performing stands on a hard surface, the correlation coefficients ranged from 0.591 to 0.684, and on a soft surface, from 0.618 to 0.687. In other words, in all cases, the values of the coefficients confirmed the average level of validity of the SHC method of recording test results.

Another criterion used to determine the best method of recording results was reliability. The data for girls showed both a common trend and specific features. The trend was significantly higher coefficient values when using the SHC method of recording results than the T method. This was confirmed by the authenticity coefficient values (rtt), which were as follows when the test was performed on a hard surface: standing on two legs with the T-method – 0.671, SHC-method – 0.809, standing on one leg – 0.355 and 0.912, respectively, tandem stance – 0.511 and 0.901. In other words, the use of the T-method ensured average reliability of the test results, while the SHC-method ensured high reliability (see Table 1).

A similar result, except for the reliability coefficient values, was obtained when comparing the data of the same girls, but obtained after they performed the specified stands on a soft surface. A distinctive feature here was the even higher reliability of recording the result using the SHC method (rtt within 0.915-0.951) and lower

reliability using the T-method (rtt within 0.411-0.466) than in the previous case

In the sample of boys, the analysis of data on the validity and reliability of each method used to record results in BESS revealed certain trends and features. One of the trends was a significant discrepancy in the level of validity and reliability of the methods used. In particular, the validity of the T-method when assessing standing on two legs on a solid surface was rtt = 0.331, while recording the result using the SHC-method was rtt = 0.601 (Table 2).

Performing the same stances, but on a soft surface, showed similar trends and characteristics, with the exception of the correlation coefficients. They were as follows: for the T-method of fixing the result in a two-leg stance – rtt = 0.182, for the SHC-method – rtt = 0.618; in the one-leg stance – 0.198 and 0.687, respectively, in the tandem stance – 0.231 and 0.675. As can be seen, each pair of coefficient values was characterized by low and medium values, where the former characterized the validity of the T-method, and the latter – the SHC-method of recording results in the test.

Reliability was significantly higher when using the SHC method compared to the T-method. Thus, the correlation coefficients (rtt) when performing the test on a hard surface were as follows: balance on two legs with the T-method of recording – 0.617, with the SHC-method – 0.812, balance on one leg – 0.342 and 0.918, respectively, tandem balance – 0.482 and 0.902. In other words, when using the T-method, reliability was average, while when using the SHC-method, it was high (see Table 2).

Table 2 – Sample Demographics (OV – boys, n = 22)

Statistical parameters	BESS tasks and measurement results in the firm surface (number of errors)					
	Double-legged stance		Single-legged stance		Tandem stance	
	T	SHC	T	SHC	T	SHC
Mean	0.28	0.10	3.91	2.03	1.22	0.29
± SD	0.61	0.13	2.41	1.12	0.98	0.18
Median	0	0	4.0	2.0	1.0	0
V (%)	26.25	8.73	28.65	14.02	31.64	16.17
rtt						
reliability	0.617	0.812	0.342	0.918	0.482	0.902
validity	0.331	0.601	0.223	0.679	0.324	0.684
BESS tasks and measurement results in the foam surface (number of errors)						
Mean	0.67	0.17	7.72	2.95	4.16	1.67
± SD	0.54	0.21	2.28	1.42	1.81	0.32
Me	0.5	0	7.0	2.0	4.0	1.0
V (%)	34.11	14.52	33.54	10.11	32.55	15.17
rtt						
reliability	0.466	0.915	0.411	0.954	0.427	0.931
validity	0.182	0.618	0.198	0.687	0.231	0.675

When recording the result in a one-leg stance, rtt was 0.223 and 0.679, respectively, and in a tandem stance, it was 0.324 and 0.684. In other words, in all cases, the validity of the T-method was low, while that of the SHC-method was average. A similar result, except for the correlation coefficient values, was obtained when comparing the data of the same boys, but obtained after they performed the specified stances on a soft surface. A distinctive feature here was that the correlation coefficients were even higher than in the previous case when using the SHC method. They ranged from rtt = 0.915 to rtt = 0.954 (high level), while the reliability of the T-method of recording

the result was described by values from rtt = 0.411 to rtt = 0.466, i.e., it was at an average level.

SEN samples. After recording the results of the girls using each method, it was found that the T-method is characterized by an average level of validity, with the exception of standing on one leg, where the level was low. At the same time, these levels were noted in the recording of results in girls with both cardiovascular and nervous system diseases. According to these samples, the rtt values were as follows: standing on two legs – 0.406 and 0.386, standing on one leg – 0.256 and 0.291, tandem stance – 0.348 and 0.351 (Tables 3 and 4).

Table 3 – Sample Demographics (SEN – girls with cardiovascular diseases, n = 20)

Statistical parameters	BESS tasks and measurement results in the firm surface (number of errors)					
	Double-legged stance		Single-legged stance		Tandem stance	
	T	SHC	T	SHC	T	SHC
Mean	0.97	0.21	4.35	2.71	1.93	0.35
± SD	0.49	0.19	2.02	1.16	1.09	0.27
Median	1.0	0	4.0	2.0	2.0	0
V (%)	40.11	10.24	31.92	18.21	24.14	16.44
rtt						
reliability	0.594	0.901	0.343	0.922	0.529	0.914
validity	0.406	0.623	0.256	0.609	0.351	0.677
BESS tasks and measurement results in the foam surface (number of errors)						
Mean	0.82	0.12	8.15	3.45	4.41	1.73
± SD	0.49	0.14	2.49	2.21	1.88	0.98
Me	1.0	0	8.0	3.5	4.0	1.5
V (%)	26.45	11.32	36.43	20.85	29.21	19.28
rtt						
reliability	0.488	0.911	0.423	0.922	0.421	0.927
validity	0.185	0.607	0.211	0.728	0.227	0.683

Table 4 – Sample Demographics (SEN – girls with nervous system diseases, n = 14)

Statistical parameters	BESS tasks and measurement results in the firm surface (number of errors)					
	Double-legged stance		Single-legged stance		Tandem stance	
	T	SHC	T	SHC	T	SHC
Mean	1.11	0.37	7.11	3.32	2.41	0.49
± SD	0.67	0.21	2.87	1.89	1.15	0.21
Median	1.0	0	7.0	3.0	2.0	0
V (%)	34.23	20.02	28.52	19.79	28.47	17.81
rtt						
reliability	0.544	0.900	0.356	0.934	0.505	0.925
validity	0.386	0.615	0.291	0.621	0.348	0.727
BESS tasks and measurement results in the foam surface (number of errors)						
Mean	1.24	0.44	9.68	3.61	5.23	2.27
± SD	0.58	0.24	2.51	2.19	1.89	1.97
Median	1.5	0.5	9.0	3.5	5.0	2.0
V (%)	28.71	15.83	32.93	18.37	31.44	15.32
rtt						
reliability	0.469	0.909	0.423	0.922	0.427	0.907
validity	0.215	0.659	0.212	0.741	0.224	0.663

Another level of validity was noted in the T-method of recording test results on a soft surface. The same girls performing the test stands resulted in the following rtt values: standing on two legs – in the “cardiovascular system disease” sample, the value was 0.185, in the “nervous system disease” sample - 0.215; one-leg stand – 0.211 and 0.212, respectively; tandem stand – 0.227 and 0.224. All of the above values were in the range from 0 to 0.3, i.e., they reflected a low correlation between the studied indicators. In other words, the validity of the T-method of recording results in BESS was low.

A completely different result was obtained when analyzing data on the use of the SHC method of recording results in BESS. This was evidenced by the correlation coefficients (rtt) obtained during the determination of the validity of this method of recording results. Thus, when performing handstands on a hard surface, the coefficients in the sample of girls with cardiovascular diseases were within the range of 0.623-0.677, and in the sample of girls with nervous system diseases – 0.615-0.727 (see Tables 3 and 4). When performing the same handstands, but on a soft surface, the validity of the results was reflected in the following rtt values: in the sample of girls with cardiovascular diseases, within the range of 0.607-0.728, in the sample of girls with nervous system diseases – 0.659-0.741. In other words, all the values were within the range of 0.601-0.7 and 0.701-0.9, which indicated, respectively, medium and high strength of correlation

between the studied indicators, i.e., at least an average level of validity of the T-method of recording the results of girls in BESS.

Analysis of the data according to the reliability criterion revealed certain trends and features of the process. The trend was significantly higher coefficients obtained when using the SHC method of recording test results than the T method. This was confirmed by the correlation coefficients (rtt), which were as follows when the test was performed on a hard surface: standing on two legs using the T-method – 0.671, SHC-method – 0.809, standing on one leg – 0.355 and 0.912, respectively, tandem stance – 0.511 and 0.901. In other words, when using the T-method, reliability corresponded to the average level, and when using the SHC-method, to the high level (see Tables 3 and 4).

A similar result, except for the reliability coefficient values, was obtained when comparing the data of the same girls, but after they performed the specified stands on a soft surface. A distinctive feature here was that the correlation coefficient values were even higher than in the previous case when the result was recorded using the SHC method (rtt within 0.915-0.951) and lower when recorded using the T method (rtt within 0.411-0.466).

The study of data obtained during testing of boys with diseases of the cardiovascular and nervous systems revealed trends and characteristics very similar to those found in girls (Tables 5 and 6).

Table 5 – Sample Demographics (SEN – boys with cardiovascular diseases, n = 22)

Statistical parameters	BESS tasks and measurement results in the firm surface (number of errors)					
	Double-legged stance		Single-legged stance		Tandem stance	
	T	SHC	T	SHC	T	SHC
Mean	0.72	0.15	4.58	2.13	1.91	0.31
± SD	0.44	0.11	2.16	1.04	1.12	0.20
Me	1.0	0	4.0	2.0	1.5	0
V (%)	34.51	9.72	32.52	14.32	25.48	15.12
rtt						
reliability	0.417	0.903	0.381	0.915	0.478	0.908
validity	0.212	0.661	0.224	0.597	0.238	0.684
BESS tasks and measurement results in the foam surface (number of errors)						
Mean	0.79	0.16	8.09	3.45	4.39	1.71
± SD	0.44	0.13	2.31	2.21	1.74	0.64
Me	1.0	0	8.0	3.5	4.0	1.5
V (%)	25.05	13.12	34.21	20.85	27.35	13.98
rtt						
reliability	0.477	0.914	0.401	0.918	0.421	0.942
validity	0.192	0.615	0.223	0.718	0.227	0.724

Table 6 – Sample Demographics (SEN – boys with nervous system diseases, n = 12)

Statistical parameters	BESS tasks and measurement results in the firm surface (number of errors)					
	Double-legged stance		Single-legged stance		Tandem stance	
	T	SHC	T	SHC	T	SHC
Mean	0.98	0.32	7.22	3.21	2.36	0.41
± SD	0.58	0.22	2.71	1.83	1.19	0.24
Me	0	0	7.0	3.0	2.0	0
V (%)	31.12	19.87	29.45	17.19	26.94	18.11
rtt						
reliability	0.535	0.902	0.359	0.935	0.508	0.921
validity	0.389	0.629	0.301	0.621	0.334	0.731
BESS tasks and measurement results in the foam surface (number of errors)						
Mean	1.08	0.24	9.44	3.43	5.03	2.04
± SD	0.52	0.18	2.47	2.11	1.77	1.66
Me	1.0	0	9.0	3.0	5.0	2.0
V (%)	32.87	15.38	35.67	19.94	30.87	15.82
rtt						
reliability	0.457	0.911	0.420	0.929	0.417	0.918
validity	0.221	0.664	0.215	0.732	0.212	0.667

Specifically, we note that the validity of the T-method of recording the results of boys when performing tasks on a hard surface was at low and medium levels. This was evidenced by the correlation coefficients (rtt), which ranged from 0.212 to 0.238 (sample “cardiovascular system diseases”) and 0.301 to 389 (sample “nervous system diseases”). When using the SHC method, the correlation coefficients ranged from 0.591 to 0.684 and 0.621 to 0.731, respectively. These values indicated that

in both samples, the validity of this method of recording results in BESS corresponded to the average level.

When the same boys performed similar tasks, but on a soft surface, the correlation coefficients obtained indicated low validity of the T method and high validity of the SHC method of recording results.

As for the reliability of the methods used to record results, it was not the same when the test was performed on a hard surface. The T-method provided an average

level of reliability in both samples of boys (rtt within 0.381-0.487 and 0.359-0.535), while the SHC method provided a high level (rtt within 0.903-0.915 and 0.902-0.935). When performing the test on a soft surface, the reliability was as follows: when using the T-method, average in both samples (rtt within 0.401-0.477 and 0.417-0.455), when using the SHC method, high (rtt within 0.914-0.942 and 0.911-0.929).

Discussion

The high-tech capabilities of modern electronics today make it possible to successfully solve various problems in physical therapy, physical education, and children's sports activities [9]. Some of the main ones are: correct and effective assessment of the results of solving various pedagogical and rehabilitation tasks; quick receipt of all information regarding test results; solving other, but also important tasks of monitoring various characteristics of the child [18; 19; 41]. It has been reported [28] that the use of technical means, namely portable sensors, ensures the objectivity of balance measurement. The results of our study are consistent with those reported and obtained by other researchers [9; 10] regarding the effectiveness of computerized programmable devices in achieving objectivity in assessing test results in general and various types of coordination in particular. In addition, taking into account information from specialized literature, we noted that our study corresponds to current trends in the modernization of systems for recording and evaluating the test results of children and young people used in pedagogy, primarily in physical education, physical therapy, and children's sports [13].

During the study, it is also important to take into account the fact that proposals for the use of tools based on the latest electronics require mandatory verification of compliance with metrological requirements [34]. First of all, we are talking about the provisions of test theory regarding authenticity, namely the validity and reliability of research tools [39]. These characteristics are extremely important because they ensure that the results of using a particular tool will be accurate, consistent, and reliable [14]. In this regard, it is noted [29] that determining validity and reliability are necessary steps in evaluating the tool that the researcher plans to use. In terms of our study, it is crucial to note that manually obtained balance assessments cannot be accurate. One of the main reasons is that most changes cannot be detected with the naked eye [32; 33].

A small number of studies have been devoted to examining the reliability of the traditional method of recording results in BESS, which has been demonstrated by middle and high school students [8], a healthy population of children aged 5-9, 10-13, adolescents and young people aged 14-18, 19-23 [30]. At the same time, information from

researchers [11; 34] indicates that the reliability of the overall assessment of BESS results by specialists ranges from low to medium. This was confirmed in our study, in particular, it was found that this result is characteristic not only for the healthy population of adolescents and young people but also for peers with special educational needs, although with certain peculiarities. The latter is partly confirmed by the results of C. M. A. L. Júnior et al [21] regarding the scientific validity of an already validated set of tests for assessing the motor coordination of wheelchair users.

In addition, the study expands the understanding of the importance of postural stability as the body's ability to maintain balance, effectively counteract its disruption, and ensure stability through the coordinated activity of the somatosensory system, vestibular apparatus, vision, and proprioception [3; 17; 23]. The data obtained can be used as a basis for developing personal physical activity programs aimed at solving the tasks of physical therapy and physical education for children and adolescents.

Conclusions

One of the current trends in physical education, physical therapy, and children's sports is the modernization of systems for recording and evaluating the test results of children and young people based on computerized programmable devices.

A software and hardware complex (SHC) has been developed, which is a software and hardware system for controlling the execution and recording of results in BESS. It is based on the integration of modern hardware and neural network technology, as well as algorithms for processing test results using application software.

The proposed complex allows real-time recording and processing of test results and obtaining summary information with a fairly high degree of objectivity, accuracy, and reliability. The correlation coefficients demonstrated a high degree of reliability and above-average (from rtt) validity of the proposed tool.

The use of the proposed SHC by girls and boys aged 14-17 from a healthy population and with special educational needs due to diseases of the cardiovascular and nervous systems led to practically the same validity and reliability in the application of the proposed SHC. However, in all cases, it prevailed over the traditional (visual) method of recording results in BESS.

Objective, accurate, and reliable information obtained using the proposed SHC can significantly increase the effectiveness of personal physical activity programs for improving coordination in adolescents and young people in general and postural stability in particular.

Conflict of interest. The authors declare the absence of any conflict of interest.

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