INSTRUMENTAL FIXATION OF LOWER LIMB MOVEMENTS COORDINATION IN PRESCHOOL CHILDREN

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The article examines the parameters of metrological characteristics used to record the results of testing the coordination of lower limbs using the device we developed and in the traditional manner. *The aim of the study* was to experimentally determine the effectiveness of using a device developed on the basis of the latest electronics to record the results of the lower limb coordination test in preschoolers. *Material and methods.* The study involved 42 children aged 6 years, of whom 21 were girls (6.1±0.2 years) and 21 were boys (6.0±0.4 years). The children had no health abnormalities and were selected randomly from a total sample of 84 children. The developed device was used to record the results of the foot-tapping test (FTT), which allows assessing the development of lower limb coordination. The following metrological characteristics of the results were determined: reliability and validity. We analyzed separately the data of girls and boys obtained after each of the three monthly tests. We compared the results obtained by the traditional method of their registration and those obtained using the device we developed. *Results*. Recording the results of children performing the FTT test by the traditional method (visual assessment of the result) and using the device we developed showed the existence of a discrepancy in their reliability and validity. The values of their coefficients showed that the second method was significantly better than the first. Thus, for girls, the reliability coefficients were within 0.895-0.907, for boys – 0.890-0.901, the validity coefficients – respectively within 0.607-0.648 and 0.602-0.610. In all cases, such coefficient values indicated a fairly high degree of reliability and validity. The traditional method of recording the results was characterized by a low degree of validity and reliability. In addition, no differences were found in the average results of girls and boys, which indicated a similar trend in the development of coordination of movements of the lower extremities. *Conclusions*. When studying the specified type of coordination in preschool children, it is advisable to use the device we developed to record the results. Monitoring the development of coordination should be carried out systematically. When analyzing the data obtained, it is not necessary to form a separate sample of girls and boys.

Keywords: children, preschool period, coordination, evaluation of the result, reliability, validity.

Siedlaczek-Szwed Aleksandra, Галаманжук Леся, Єдинак Геннадій, Блавт Оксана. **Інструментальна фіксація у дошкільників координації рухів нижніми кінцівками**

Анотація. У статті розглянуто параметри метрологічних характеристик, якими відзначалася фіксація результатів тестування координації рухів нижніми кінцівками з використанням розробленого нами приладу та у традиційний спосіб. *Мета дослідження* полягала в експериментальному визначенні ефективності використання приладу, розробленого на основі новітньої електроніки, для фіксації у дошкільників результатів виконання тесту на координацію рухів нижніми кінцівками. *Матеріал та методи*. У дослідженні взяли участь 42 дитини віку 6 років, з яких 21 дівчинка (6.1±0.2 років) і 21 хлопчик (6.0±0.4 років). Діти не мали відхилень у стані здоров'я, їх було обрано методом випадкової вибірки із загальної вибірки чисельністю 84 дитини. Розроблений прилад використовували для фіксації результатів у тесті «the foot-tapping test (FTT)», який дозволяє оцінювати стан розвитку координації рухів нижніми кінцівками. Визначали такі метрологічні характеристики фіксації результатів: надійність, валідність. Аналізували окремо дані дівчаток та хлопчиків, одержані після кожного з трьох щомісячних тестувань. Порівнювали результати, що були одержані традиційним способом їхньої реєстрації, та одержані за допомогою розробленого нами приладу. *Результати*. Фіксація результатів виконання дітьми тесту FTT традиційним (візуальна оцінка результату) способом та за допомогою розробленого нами приладу засвідчила існування розбіжності в їхній надійності та валідності. Значення їх коефіцієнтів свідчили, що другий зазначений спосіб суттєво кращий, ніж перший. Так у дівчаток коефіцієнти надійності знаходилися в межах 0.895-0.907, у хлопчиків – 0.890-0.901, коефіцієнти валідності – відповідно у межах 0.607-0.648 та 0.602-0.610. У всіх випадках такі значення коефіцієнтів свідчили про досить високий ступінь надійності та валідності. Традиційний спосіб фіксації результатів відзначався низьким ступенем валідності та надійності. Крім цього, не було виявлено розбіжності у середніх результатах дівчаток і хлопчиків, що свідчило про подібну тенденцію у розвитку координації рухів нижніми кінцівками. *Висновки*. Під час вивчення зазначеного виду координації у дітей дошкільного віку доцільно для фіксації результатів використовувати розроблений нами прилад. Моніторинг розвитку координації здійснювати систематично. Під час аналізу отриманих даних не обов'язково формувати окрему вибірку дівчаток та хлопчиків.

Ключові слова: діти, дошкільний період, координація, оцінювання результату, надійність, валідність.

Introduction

In the preschool period, coordination of movements develops most intensively. This physical quality is extremely important for the child. First of all, it contributes to the versatile development of the child and ensures its adequate preparation for further life and education [32]. At the same time, it is important not only to constantly develop this physical quality. It is also important to constantly monitor the achievements of children in improving the result. In other words, productive development requires constant monitoring of the appropriateness of using a wide range of physical education tools [15]. In this regard, the synergy of efforts of different fields of knowledge is focused on the use of high-tech measuring devices [5; 7; 13]. This is due to the fact that with their help it is possible to quantitatively and at a high level of objectivity assess

the results of children's motor activity aimed at developing various types of coordination in them [21].

The scientific interest of researchers from different countries of the world is focused on the possibilities of motor activity as an effective means of the general development of the child in general and his coordination of movements in particular. Currently, there is a fairly large amount of empirical data on the state of development of various manifestations of coordination in children aged 3-7 years [1; 3; 4; 12; 23]. Without stopping to analyze such data, we will only note that a large proportion of these studies use different tests to assess the same type of coordination. In addition, the methods of measuring the result in such tests do not always meet the high parameters of metrological requirements [10; 30; 33].

Specifying the question of types of coordination, we note that one of the most important is the coordination of movements of the lower extremities [20]. First of all, this is due to the fact that it ensures the performance of most daily motor actions, in particular walking, running, climbing/descending, standing, getting up and sitting down, and some others [22]. The results indicate a different state of development from the required for most types of coordination of movements in preschool children [1; 23; 28]. Some of the reasons for such a state of development are associated with disorders of the nervous, vestibular, and musculoskeletal systems of the child's body [25]. As for the diagnostic tools for this type of coordination, one of the most common in world practice is the "foot tapping test" (FTT) [10; 33]. However, relatively little is known about its reliability or normative values, both in healthy and clinical populations, for children [26]. In particular, no such study to date has determined the reliability or validity of the FTT by comparing it with several different counting methods in healthy children [27]. The results obtained by this researcher indicated the following. Despite significant differences between repeat trials for Force Plate and Video Counts (~2 foot-taps, $p < 0.01$), test-retest reliability was high for all three methods (Pearson's $R > 0.90$). Dominant foot trials were higher (~2 foot-taps, $p < 0.05$) than Non-dominant for all three counts. When performed with shoes ON, counts were higher (~2 foot-taps, $p < 0.05$) than OFF for the Live and Force Plate counts. Reliability between visits was high (ICC >0.80) and only the Video count was significantly lower for Visit 1 ($p < 0.01$).

This indicates several main aspects of the problem under study. One of them concerns the need to pay increased attention to the state of development of children's coordination of movements. In this regard, another aspect is automatically updated, namely, the control and assessment of the coordination of movements using exclusively reliable tools [18]. The mainstream here is the high-tech capabilities of the latest electronics [6; 7]. To some extent, this is confirmed by empirical data on the effectiveness of the use of electronic technologies in monitoring the results of physical activity [2]. In addition, it has been established [14; 15; 31] that the use of electronic technologies in monitoring the results of solving various physical activity tasks allows: to evaluate them correctly and effectively; to provide quick access to all information obtained during testing.

Taking into account all the above information, the need to conduct research aimed at testing the effectiveness of the device for monitoring the coordination of movements of the lower extremities of preschool children was noted. It should be noted here that a special study [8] established a fairly high efficiency of the device used in our study. However, this device was used by students with functional disorders of the lower extremities.

Purpose of the research – to experimentally determine the efficiency of using a device developed based on the latest electronics for recording the results of lower limb coordination tests in preschoolers.

Materials and methods

Research methods. The methods that were selected for the implementation of the study corresponded to the goal and objectives. The main ones were analysis, systematization (used to process information sources), testing, and methods of mathematical statistics. As for the organization of the study, its basis was a systematic approach. It provided for several stages, and the first one provided for obtaining complete, objective and reliable information about the state of the study of the issue being studied. In the second stage, the test results were compared, namely those obtained in each attempt, to identify discrepancies between them [19]. The third stage was to summarize the information obtained during the comparison. The fourth stage was to formulate conclusions and compare the results of our experiment with others related to the problem under study.

The selected test for monitoring the level of development of coordination of movements of the lower extremities, the foot-tapping test (FTT), is the simplest and easiest to use motor action that does not require complex equipment. The test must be performed in a sitting position on a chair, lasts less than one minute, and therefore eliminates the possibility of fatigue.

Study participants. Given that the degree of authenticity of the test significantly depends on the degree of homogeneity of the sample, the selection of the contingent was carried out taking into account important defining characteristics. In particular, a total of 42 children aged 6 years were involved in the study, of which 21 were girls (6.1±0.2 years) and 21 were boys (6.0±0.4 years). All children had no abnormalities in their health, they were selected by random sampling from a total sample of

84 children (41 girls and 41 boys) of the specified age. The study was based on two preschool educational institutions, each with an equal representation of girls and boys, which formed the total sample. All parents provided written 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. The child sat on a height-adjustable chair, with the hips and knees at approximately 90°, and the feet placed on two rubber mats. The feet in the shoes were positioned in such a way that when the subject's sole was flexed and the foot touched the floor, only the ball of the foot touched the plate, which allowed the number of taps to be counted. The foot position was maintained constant between trials using a grid system on the plates

To perform the test correctly, children were first taught to perform the necessary foot movement with each leg. Only then were the children tested. The child performed the following actions: tapped the ball of the foot on the rubber mat as quickly as possible, holding the heel firmly; pressed the heel to the floor. The performance occurred in a comfortable and consistent range of motion during the tapping, as long as it allowed the ball of the foot to be fully released between taps. The child was given a countdown (3, 2, 1 and GO) before the start of the tapping and 1-2 minutes of rest between attempts. There were 2 attempts: the first for the non-conducting leg, and the second for the conducting leg. The time for each attempt was 10 seconds. Such attempts were implemented twice during one day, namely starting at 9.30 and after the children's daytime sleep at 15.30. This time was chosen because the children were in practically the same state due to a long rest.

Research organization. The study was carried out by the principles of ethics of empirical research. It was aimed at obtaining empirical facts. The accumulation of the necessary information took place in two directions. One of them involved the use of the traditional method of fixing the FTT results, that is, using a visual inspection in real-time by the experimenter during testing. The other direction involved the use of an experimental factor aimed at avoiding elements of subjectivity that are characteristic of the traditional method of determining the result of the test. The basis of the experimental factor was the method of fixing the FTT result using the device we developed. Taking into account the purpose of the study, in each of the indicated directions the average result of two attempts was used. The reliability of the experimental results was ensured by using the "test-retest" method, but testing was carried out three times, namely once a month. During each test, great importance was attached to creating the same conditions for its conduct. For this, before the start of each test, the children received the necessary instructions, and the experimenter perfectly mastered the testing methodology. In particular, he had the necessary skills in organizing and implementing the testing procedure, as well as obtaining its results.

Statistical analysis. The empirical data obtained during each test were processed by adequate methods of mathematical statistics. SPSS version 22.0 (IBM Corporation) was used for this, which allowed determining the arithmetic mean (M), standard deviation of the mean (S), and coefficient of variation (V). In addition, quantitative characteristics were determined that allowed the establishment of the authenticity of the FTT test, which involved the use of the device we developed. Taking into account the complexity and information of the researchers [29], correlation analysis (r) was chosen for this.

Results

First of all, it is necessary to clarify the information about the device, which was developed for more accurate and high-quality fixation of the result in the FTT test (fig. 2).

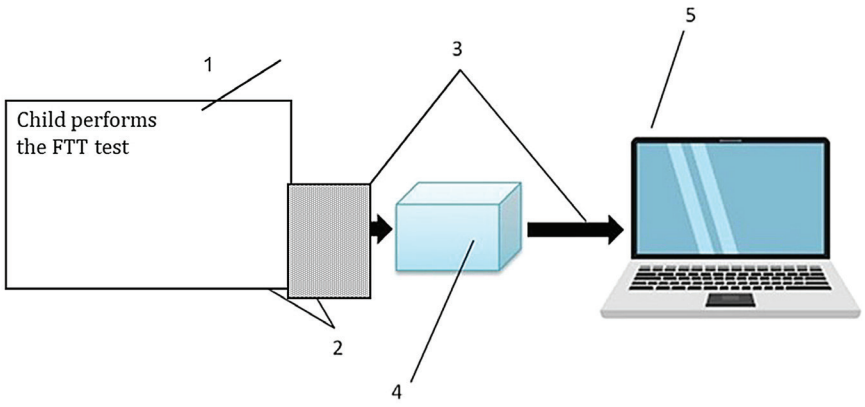

Fig. 2 Scheme of the developed device for monitoring the manifestation of coordination of movements of the lower extremities

N o t e: 1 – student, 2 – rubber mats, 3 – infrared communication lines, 4 – microcontroller, 5 – PC

The device consists of two rubber mats, in which capacitive proximity sensors are placed [16]. The device registers each touch by changing the capacitance of the sensors. When touched, an impulse occurs, which is captured by the sensor of each rubber mat and sent to the microcontroller via an infrared communication line. It forms information about the time and frequency of movements performed by each leg.

The novelty of the proposed development is that the device uses a high-performance ATMega 328P microcontroller of the "latest generation", which can support a wide range of sensors and has a large list of functions [24]. The microcontroller contains an internal built-in 32 KB flash memory, 23 input/output lines, configurable timers-counters, and 5 possible power-saving modes with the ability to balance power consumption and performance.

The signals of the child's toes touching the rubber mats, received by capacitive sensors, are processed by the microcontroller and displayed on the PC after serial connection and application of the Arduino software, which reads the received information about the test performance. In addition, the software allows you to present such information graphically. As for the capabilities of the device, it records and controls not only the number of taps, but also their duration, rhythm, speed, and some other characteristics of the leg movements. The device also guarantees access at any time to all information about the test results, which are collected in a single system. In turn, the latter makes it possible to use the available information on any personal computer at any time.

When implementing the experiment, we tried to determine the quality of the measurement results in each repeated test (Table 1).

Table 1 – Metrological characteristics of different fixation of boys' results in the FTT test (n = 21)

Statistical parameters	Test tasks and measurement results (Number of times)					
	1st attempt		2nd attempt		3rd attempt	
	T	A	T	A	T	A
M	31.4	36.7	32.8	37.6	33.7	38.9
S	5.2	4.8	5.4	4.6	5.7	4.4
V (%)	16.6	13.1	16.5	12.2	16.9	11.3
rtt						
reliability	0.501	0.890	0.492	0.898	0.477	0.901
validity	0.234	0.602	0.244	0.610	0.276	0.607

N o t e: T – the traditional way, A – using the developed tool

When analyzing the obtained data, we took into account that the theory of tests emphasizes the absence of a fixed authenticity value, which allows us to consider the test acceptable [11]. Another provision concerned the direction in which the obtained empirical data were used. In this regard, we note that the numerical values of test authenticity, which were obtained by the traditional method of fixing the results, corresponded to the "low" level. At the same time, such a result was obtained in each of the three measurements, which took place with an interval of one month. It should also be noted here that the lower limit of the permissible reliability value is usually 0.7. In our case, the test reliability coefficients were significantly lower than the lower limit. This indicated that the traditional method of fixing the child's result using the FTT test has significant measurement errors. In this case, the objectivity of the information obtained will be questionable.

In the case of fixing the results using the developed device, practically very high reliability was found. This was evidenced by the value of the reliability coefficient, which at the first stage of testing was 0.890, at the second – 0.898, and the lower limit of very high reliability – 0.900. As for the third stage of testing, the value of the coefficient increased to 0.901, i.e. it indicated a very high level of reliability in fixing the result when the child performed the FTT test. This is evidence of a very low probability of making a mistake when measuring an individual result.

At the same time, it was taken into account that such a metrological characteristic as reliability is associated with another, but no less important characteristic, namely validity [33]. In this regard, the value of the corresponding coefficient was established. The data obtained indicated that the correlation between the test results and the results of the assessment using the developed device was at the "high" level. As can be seen from Table 1, such a

level is characteristic of each of the three stages of testing.

The values of the validity coefficient at each such stage, which were obtained when using the traditional method of recording results, showed a low level of objectivity. In particular, at the first stage, the value of the validity coefficient was 0.234, at the second – 0.244, and the third – 0.276. At the same time, in the case of recording results using the developed device, the value of the coefficient increased almost threefold, reaching values within 0.602-0.610. According to the special literature [27], such values indicate a fairly high level of correlation between the results of test measurement and assessment. The values of correlation coefficients within 0.1-0.3 reflect a low level of such correlation.

We continued the research in the indicated direction, but using the data obtained from girls. We found results that were very similar to those established in boys of the same age. Thus, the test authenticity with the traditional method of recording the results corresponded to the level of «low» (Table 2).

Table 2 – Metrological characteristics of different fixation of girls' results in the FTT test (n = 21)

Statistical parameters	Test tasks and measurement results (Number of times)					
	1st attempt		2nd attempt		3rd attempt	
	T	A	T	A	T	A
M	30.5	33.8	32.1	36.9	32.2	39.1
S	5.0	5.1	5.2	4.7	5.0	4.8
V (%)	16.4	15.1	16.2	12.9	15.5	12.3
rtt						
reliability	0.511	0.895	0.491	0.902	0.490	0.907
validity	0.222	0.632	0.232	0.648	0.272	0.607

N o t e: T – the traditional way, A – using the developed tool

At the same time, such a result was obtained in each of the three measurements, which took place with an interval of one month. At the same time, in the case of fixing the results using the device that we developed, the reliability corresponded to the "high" level. This was evidenced by the value of the reliability coefficient, during the interpretation of which it was taken into account that values from 0.7 and less indicate a low level, values in the range of 0.9-1.0 - a high one.

As for another studied characteristic of fixing the results of using FTT, namely validity, a certain feature was noted here. It consisted in the fact that when using the traditional method of fixing the results, the data obtained at each of the three stages showed low correlation. In particular, the values of the correlation coefficient were in the range of 0.222-0.272. At the same time, the fixation of the test results using the developed device at the first stage of the study was marked by a correlation at the level of 0.632, at the second – 0.648, and the third – 0.607. When analyzing such data, it was taken into account that a correlation greater than 0.600 corresponds to a high level, within 0.1-0.3 – to a low level [27].

Discussion

The relevance of our study is due to the need for systematic improvement of the complex means and methods for the development of children's coordination, especially in the preschool period [3; 4; 9]. It is necessary to take into account the existence of different types of coordination that require different methods of development and test support in control. Coordination should be considered from the position of its leading importance not only for the physical but also for the cognitive and social development of the child [17]. In addition, experience contributes to the learning and development of fundamental motor skills. The foundations of these skills are laid in early childhood and are important for encouraging a physically active lifestyle. According to researchers [20; 22], one of the most important is the coordination of movements of the lower extremities, as it ensures the performance of most daily motor actions (walking, running, climbing/ descending, standing, getting up and sitting down, and some others).

At the same time, it is necessary to take into account that the development of different types of coordination can be assessed using several assessment tools. The choice of test will depend on the context in

which the assessment is planned [19]. In connection with the problem under study, it was determined that one of the main diagnostic tools for the coordination of movements of the lower extremities is the "foot tapping test" (FTT) [10; 26; 33]. Studies of its reliability, validity, and normative values are practically absent because today we have one with the participation of adults which involved comparing the results of testing using different counting methods [27].

On the other hand, globalization and the progress of modern electronics create positive prerequisites for increasing the objectivity and reliability of test control over the development of coordination in general and coordination of movements of the lower extremities in particular in preschool children [5; 6; 15].

The results of our study are consistent with the conclusions of other researchers regarding the possibility of using modern electronic equipment to obtain the necessary data, primarily to eliminate the influence of the human factor on the results of this procedure [14]. The need for the latter is due to modern provisions of sports metrology, namely, the inadmissibility of formulating conclusions based on data obtained using tests with a low level of authenticity. The greater the influence of the human factor on the fixation of test results, the more difficult it is to understand the extent of the influence of its conditions and side factors on the results obtained [24].

The novelty of the conducted study lies in the fact that until now the FTT test has been used in studies of the adult population [27], there are significantly fewer of them in studies of the coordination of school-age children [9; 28]. We have not come across scientific information about the results of testing preschool children using FTT. However, the ease of its use, minimal time consumption, and the lack of need for special equipment all make FTT a convenient tool for monitoring coordination of preschoolers.

At the same time, we note that the data we obtained did not confirm the information about a closer relationship between sensorimotor indicators and general coordination in males [8; 12]. In particular, in our study, the values of the correlation coefficients, as well as the average value of the sample, reflecting the state of development of coordination in movements of the lower extremities of girls and boys, practically did not differ when compared. One of the reasons for this result was associated with the age of children, namely, the peculiarities of growth and development processes in the period of 5-7 years, which is characterized by an intensive nature [1; 13].

Some improvement in the result was found with each new stage of testing, i.e. from the first to the third stage. In particular, the results of both boys and girls were marked by a tendency to improve. One of the possible reasons for the revealed feature was associated with the use of various motor actions by children during their physical education. The achievement of a positive result in the case of the use of various types of motor actions by preschool children is evidenced by the research of D. Stanković et al. [24]. In addition, the use of various types of motor actions contributes to the improvement of physical activity, general development and the formation of social skills [4].

Conclusions

Coordination is an extremely important motor quality for a child, therefore it requires constant development, especially in the preschool period. In this regard, the problem of qualitative control over the state of development of this quality in children becomes relevant, but primarily with the use of modern high-tech solutions.

Determination of the state of development of coordination of movements of the lower extremities in 6-year-old girls and boys using the traditional (visual assessment of the result) method of registering test results and using the device developed by us showed the existence of a discrepancy in their effectiveness. In terms of the values of reliability and validity coefficients, the second method is significantly better than the first, in obtaining more objective data on the results of children's performance on the FTT test. This was evidenced by the following values: reliability coefficients in girls were within 0.895-0.907, in boys – 0.890-0.901; validity coefficients – respectively within 0.607-0.648 and 0.602-0.610. In all cases, they indicated a fairly high level, while the traditional method was characterized by coefficient values that indicated a low level.

The average results of girls and boys performing the specified test for the development of coordination in lower limb movements were practically the same, which indicated a similar trend in this process.

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

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