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Original Article

Age peculiarities of the development of coordination abilities in children of primary school age in the process of physical education

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Abstract
The article presents the results of a study of age peculiarities of the development of coordination abilities of pupils in grades 2-4. According to the purpose of the study, we studied the age peculiarities of the development of the equilibrium function and determined the structure of the relationship of coordination abilities and biomechanical factors. Altogether 80 primary school children were involved in the educational experiment. Methods of research applied were as follows: analysis and systematization of medical and sports publications; study and generalization of advanced pedagogical practice on the issue of the investigation of the coordination abilities of primary school children; testing, educational experiment, methods of mathematical statistics.
Analysis of the results made it possible to identify the level of static and dynamic equilibrium in the process of physical education. The equilibrium function in primary school pupils develops quite intensively from grade 2 to grade 4. We found that with age in children, there is a functional improvement of the reflex mechanisms that are responsible for maintaining balance. In our study, we found that body length and body weight do not have a significant influence on the ability to keep static and dynamic equilibrium.
The results of our studies testify to a significant impact of visual and vestibular analysers on the ability to keep body position. Exercises that were performed with eyes closed had a large amplitude of body vibrations and impaired stability in all age groups. It is noteworthy that the influence of the visual analyser somewhat decreases with age.
The analysis of coordination abilities shows a statistically significant difference ($p < 0.05$; $p < 0.01$) in pupils of grades 2 and 4. We did not find a statistically significant difference ($p > 0.05$) between boys and girls during the tests. Although the indicators of static equilibrium in girls of all ages had insignificant predominant features, and, on the other hand, in boys, the results of dynamic equilibrium were higher.
Keywords: coordination abilities, balance, equilibrium, schoolchildren.

Introduction

The ability of a person to keep the position of the body in the field of earth's gravity is significant since the starting position when performing many types of movements is the orthograde position. According to the theory of biomechanics at the modern scientific level of knowledge, the human body is considered as a complex motor system, one of the tasks of which is to maintain balance based on signals about the distribution of body parts relative to each other and support, as well as about the direction of gravity, the acting accelerations, the orientation of the visual vertical (Marchenko, 2014; Koval, 2015)

Motor actions and everyday working postural poses include elements of balance, and therefore the correct and accurate execution even of relatively simple movements cannot be performed without a sufficiently high level of development of coordination abilities. Coordination abilities represent innate prerequisites for the formation of the motor function, which determine its compliance with the ergonomic requirements for the fulfilment of motor tasks that have some kinematic and dynamic parameters and at the same time allow you to choose the best ways to solve motor problems while minimizing your energy costs. The coordination characteristics of a person are complicated, and it is impossible to assess them according to one standardized criterion.

Among the factors that determine the coordination level, it is necessary to underline the comprehensiveness of perception and analysis of movements, the presence of images of dynamic, time and spatial characteristics of the movements of one's body and its various parts in their complicated interaction,

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formation of a plan and a particular way of making movements (Simen, 2019).The mechanisms of regulation of coordination abilities are complex since they are stipulated by the complex of activities of various analysers, as of the autonomic organs, nervous and muscular systems. During physical education lessons in elementary school, teachers use a large number of funds to develop the equilibrium function.

The ability of children to navigate in space and time, to quickly and accurately perform complex movements in a small, unstable bearing area achieved by improving the analysers involved in equilibrium reactions.

From literary sources, it is known (Pasichnyk, 2018) about the ambiguous participation of analysers in the management of the stable state of the human body. Significant merit in maintaining equilibrium belongs not only to the motor but also to the visual, vestibular, tactile analyser.

Practical interest among specialists in the field of physical education is caused by questions of development and control of coordination abilities of schoolchildren in the process of physical education (Galan, 2016; Tomenko, 2017; Bolotin, 2017; Galan, 2017).

Materials and Methods

To study coordination abilities, in particular, the level of the equilibrium function in primary school children, we used the following research methods: theoretical analysis of scientific literature, a study of documentary materials, pedagogical observation and timing of a physical education lesson, control test method, educational experiment, and mathematical statistics methods.

In our research, we combined methods that are widely used in the practice of physical education. The first group included control exercises (tests), which determined the ability to keep a particular position of the body for a long time. This group included control exercises that were performed in conditions of the decreased support area. The second group included methods that determined the accuracy of movement in a given direction, as well as exercises in conditions of irritation of the vestibular apparatus, and control exercises that were performed with the visual analyser turned off.

The principal place in our research was held by the summative pedagogical experiment, which was carried out based on the general educational establishments of the city of Chernivtsi No. 33, No. 27, No. 6 during September-May 2018-2019 academic year. Altogether 80 schoolchildren took part in the experiment: 27 pupils of grade, 23 pupils of grade 3, 30 pupils of grade 4. In each experimental age group, there were boys and girls. During the study, the following results were recorded: 1) the Romberg test in various modifications (c); 2) the Flamingo Balance test (c); 3) two-legged jumping, starting position - arms on the nape (m); 4) two-legged jumping, starting position - arms rearward (s); 5) walking forward, with gymnastic stick balancing on the palm, m; 6) shuttle running 4 × 9 m (s); 7) walking on a straight line after 5 turns around (cm); 8) walking with eyes closed on a straight line (m); 9) walking on a straight line backwards, eyes closed (m).

Results

To determine the age-related peculiarities of coordination abilities of the primary school pupils, we conducted an educational experiment, which lasted for one academic year. During the execution of motor balance tests, children were offered to perform exercises on both the left and right legs. The study was conducted in the gym, pupils were in traditional sports uniforms. The conditions and equipment throughout the experiment were stable and did not change. We selected 10 test exercises; exercises were both static and dynamic, its result was a quantitative indicator. The study of the equilibrium function by means of exercises was carried out at the same time. At first, the pupils were shown exercises and explained the tasks. Each of the schoolchildren could perform two or three attempts, such number of attempts do not have a training effect.

To complete the test task, several pupils were called; doing it we introduced a competitive effect which allowed us to assess the maximum capabilities of the pupils. The main results of the study, processed using the mathematical statistics methods, are presented in tables 1 and 2. The function of static equilibrium was studied by using the Romberg test, the results are presented in Table 1.

It is noteworthy that the average age results in the Romberg test in boys are somewhat lower than in girls. During the performance of this motor test, significant fluctuations of the body were observed in girls and boys, and the ability to long-term static equilibrium was seen only in some individual cases. When performing a complicated Romberg test with eyes closed, there were cases when children were unable to keep their balance at all; it indicates a significant influence of the visual analyser.

As can be seen from Table 1, in boys of grade 3 there is a negative dynamic, while in girls, on the contrary, there is a little age-related increase in the results in the Romberg test. As a rule, while maintaining static equilibrium, children to a greater extent tilted to the left side 67.5% (n = 54) and the right side 26.3% (n = 21), the remaining children bent either forward or backward

Table 1. Age dynamic of coordination abilities in primary school children

Indicators under study	Pupils of the 2nd grade (n=27)		Pupils of the 3rd grade (n=23)		Pupils of the 4th grade (n=30)	
	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$	S
Boys: grade 2 (n=14); grade 3 (n=11); grade 4(n=16)						
Romberg test with open eyes, second	4.2	1.26	4.1	1.18	5.9	1.27
Romberg test with eyes closed, second	2.2	0.83	2.1	0.74	2.6	0.81
The Flamingo Balance Test, number of errors	13.5	1.23	13.6	1.21	11.2	1.04
Two-legged jumping. Starting position – arms on the nape, m	7.5	0.75	10.9*	0.74	14.4**	0.85
Two-legged jumping. Starting position – arms rearward, m	7.1	0.67	10.2*	0.52	14.3**	0.48
Walking forward, with gymnastic stick balancing on the palm, m	4.5	0.38	7.9*	0.37	9.6**	0.32
Shuttle running 4 × 9 m, sec	14.1	0.81	13.7	0.66	13.1*	0.47
Walking on a straight line after 5 turns around, cm	142.7	0.53	133.4	0.58	84.8**	0.41
Walking on a straight line with eyes closed, m	8.7	0.77	9.3	0.49	11.4*	0.44
Walking backwards on a straight line with eyes closed, m	4.7	0.51	6.5	0.33	8.2**	0.49
Girls : grade 2 (n=13); grade 3 (n=12); grade 4 (n=14)						
Romberg test with open eyes, second	4.4	1.15	5.6	1.26	6.2*	1.35
Romberg test with eyes closed, second	2.1	0.94	2.3	0.87	2.9	0.92
The Flamingo Balance Test, number of errors	12.3	1.17	12.6	1.42	10.1	0.82
Two-legged jumping. Starting position – arms on the nape, m	6.3	0.66	9.2*	0.39	14.1*	0.42
Two-legged jumping. Starting position – arms rearward, m	7.0	0.59	8.7	0.52	13.7**	0.48
Walking forward, with gymnastic stick balancing on the palm, m	4.4	0.38	6.9*	0.37	9.4**	0.32
Shuttle running 4 × 9 m, sec	14.2	0.47	13.8	0.39	13.2*	0.45
Walking on a straight line after 5 turns around, cm	142.5	0.27	131.2	0.29	96.1**	0.26
Walking on a straight line with eyes closed, m	7.2	0.89	8.9	0.38	10.9*	0.44
Walking backwards on a straight line with eyes closed, m	4.2	0.36	6.3*	0.25	7.1**	0.41

Note: * the difference is statistically significant at the level of $p < 0.05$;

** the difference is statistically significant at the level of $p < 0.01$ compared with pupils of grade

During Flamingo test, which also characterizes static balance, and consists in balancing on one leg with a limited area, a significant number of younger pupils were unable to complete the test task for the first time and made more than 15 errors in the first 30 seconds.

Among children of the 2nd grade, on the first attempt, the Flamingo test was performed by 42.8% (n = 8) of boys and 46.1% (n = 6) of girls, among pupils of the 3rd grade, 45.5% (n = 5) of boys and 50. 0% (n = 6) of girls, among pupils of the 4th grade 50.0% (n = 8) of boys and 57.1% (n = 8) of girls. Although the number of errors in performing this test in boys and girls decreases with age, a large percentage of children with a low level of static equilibrium remains. The results obtained indicate that performance of this exercise on a limited area creates difficult conditions for keeping equilibrium for pupils and allows us to perform a more precise measurement of static equilibrium. We were not able to detect gender differences in the development of the function of static equilibrium. We used several test tasks characterizing the level of development of the dynamic equilibrium function. The pupils were offered to jump on two feet forward on a 15-meter distance, the starting positions - arms on the nape and arms rearward. The results indicate that in boys, the average group results in all age groups are somewhat higher than in girls. There is also a regular positive dynamic in both gender groups from the 2nd to the 4th grade. We found out that boys of grade 3 and 4 significantly ($p < 0.05$; $p < 0.01$) improve the results in performing these motor tests. In girls in grades 3 and 4, the results of jumping forward with the arms on the nape are significantly ($p < 0.05$; $p < 0.01$) improved, and the results in jumping forward with arms rearward are significantly increased ($p < 0.01$) only in the 4th grade.

The next test specified dynamic equilibrium and involved walking forward with a stick balancing on the palm of a hand. It should be pointed out that the gymnastic stick, which was in the palm of a pupil's hand during testing, significantly changed the results. In the gender and age group of children of grade 2, the lowest results are observed; the difficulties arose because of simultaneous balancing and walking forward. Reliably ($p < 0.05$; $p < 0.01$) higher indices are observed in the gender and age groups of children of grades 3 and 4, compared with children of grade 2. It indicates the development of this motor ability in children with ageing.

The next test task was to run 4 by 9-meters distances moving cubes about. This motor test is included in the physical education program for pupils of grades 2-11 of secondary school. In pedagogical practice, it is used to assess dexterity. It was easy for pupils to complete this task. The results obtained indicate significantly ($p < 0.05$) higher indicators in the schoolchildren of grade 4 of both gender groups. We used a test characterizing dynamic equilibrium; a peculiarity of the test was the performance of five turns around, after which it was necessary to go on a straight line, the distance of deviations was recorded. We found out that pupils of grade 2 of both sex groups have almost the same average group results. In girls of grade 3, the average group result is better than in boys. The results of schoolchildren of grade 4 of both gender groups are significantly ($p < 0.01$) higher than in the schoolchildren of grade 2. The results indicate a significant influence of the vestibular analyser when performing a motor task. With age, in the pupils performing this task, the distance of deviations is significantly reduced. We used several motor tests, during which children eyes should be closed. At a 15-meter-long distance, pupils had to walk with their eyes closed in the usual way and back forward. The results obtained in pupils of grades 2-4 of both gender groups indicate a significant advantage in the test of passing the distance forward with eyes closed. The average group results are almost two times higher than the results of overcoming the distance backwards. It should be noted that boys in grades 2-4 performed tests better than girls.

To determine the influence of body length and body weight in particular on coordination abilities, we performed a correlation analysis, the results of which are presented in Table 2. For the correlation analysis, boys and girls were combined into one group, since did not find out any statistically significant difference during testing between them.

Table 2. Correlation relationship between biomechanical factors and coordination abilities in the children of grades 2-4.

Indicators under study	Body length, cm	Body weight, kg
Romberg test with open eyes, second	0.004	0.012
Romberg test with eyes closed, second	0.013	-0.061
The Flamingo Balance Test, number of errors	0.107	0.082
Two-legged jumping. Starting position – arms on the nape, m	0.160	0.112
Two-legged jumping. Starting position – arms rearward, m	0.125	0.041
Walking forward, with gymnastic stick balancing on the palm, m	0.189	0.032
Shuttle running 4 × 9 m, sec	0.124	0.106
Walking on a straight line after 5 turns around, cm	0.061	0.054
Walking on a straight line with eyes closed, m	0.023	0.005
Walking backwards on a straight line with eyes closed, m	0.011	0.017

Notes: n=80; $r_{кр}$=0.217

As can be seen from Table 2, the results allow us to conclude that body length and body weight of children of grades 2-4 do not influence on the coordination abilities. The dynamics of the results of static and dynamic equilibrium mainly depend only on the age of the pupils.

Discussion

In accordance with the most advanced positions of the physiology and psychology of activity, cybernetics, and the biomechanics of physical exercises, where the principal part in the motion control system is given to the categories of optimality and purposefulness, the chief criteria for assessing coordination features are considered four main qualities: correctness, speed, rationality, and quick-wittedness. They, in their turn, have qualitative and quantitative characteristics. The speed as a criterion for assessment of the coordination features is in the form of the speed of performing complicated coordination actions of motor moves, the speed of restructuring their actions in conditions of time pressure, the speed of mastering new motor qualities (Bistra, 2018; Ferreira, 2019). It should be borne in mind that each of the above criteria for assessing coordination properties is quite complicated and ambiguous, therefore, when talking about accuracy, it is necessary to distinguish, for example, recovery accuracy, estimation accuracy, reaction accuracy, target accuracy or pointedness. A number of particular factors identified in the structure of coordination properties: coordination of movements involving large muscle groups of the whole body, coordination of movements of various parts of the body, hand-eye and eye-foot coordination; coordination of small movements; speed adjustment of motor action; spatial orientation; motor memory; equilibrium; ability to learn new motor actions; general sports training.

The brief analysis shows the complexity and significance of all the criteria for assessing coordination characteristics. They manifest themselves in actual types of motor activity and are combined in different ways with each other. The results of our investigations were confirmed in the following scientific papers: about the low level of static equilibrium in schoolchildren - (Vaskan, 2019; Galan, 2019; Abramova, 2019; Trufanova, 2019); about the low level of dynamic equilibrium in primary school pupils - (Marchenko, 2014).

The results of our study supplemented the scientific work (Krutsevich, 2003; Scalia, 2006) on the impact of the visual and vestibular analyser on the level of static and dynamic equilibrium in primary school children.

Conclusions

So, the coordination abilities of pupils of grades 2-4, which we studied in the process of physical education, are characterized by a low level of static equilibrium with the participation of the visual and vestibular analyser. During the exercise with the eyes closed, the individual result worsened from 20.0% to 63.0% in the boys and girls. The obtained average group results in motor tests indicate the intensive development of static and dynamic equilibrium in the period from grade 2 to 4. In our study, we found a lack of correlation between the equilibrium function and the length and body weight of primary school children.

Conflicts of interest

The authors declare that they have no competing interests.

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