THE INFLUENCE OF THE VESTIBULAR ANALYZER

FUNCTIONAL CONDITION ON THE PHYSICAL FITNESS OF SCHOOL-AGE CHILDREN

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Purpose: to define the extent to which the pupils' (aged 7-15) level of physical fitness changes under the influence of the special exercises on the vestibular analyser. Material: a number of researches were conducted on the basis of Kharkov comprehensive educational institutions. More than 800 pupils, out of whom 6 experimental and 6 control groups were made, took part in them. Results: the functional condition of the vestibular analyser and the pupils' level of physical fitness were investigated; distinctions of the studied indicators in age and gender aspects were considered; the interrelation between the vestibular sensory system resistance and rotational loadings, as well as the development level of the pupils' physical qualities was defined; the extent to which specially oriented exercises influence the vestibular analyser functional condition and physical fitness of examinees was revealed. Conclusions: 1. As a result of the initial researches, the insufficient level of vestibular analyser resistance in rotational loadings was established. 2. The correlation analysis showed the existence of a rather narrow interrelation between the vestibular analyser functional condition and the development level of physical qualities. 3. Application of specially selected exercises positively affected the functional condition of the vestibular analyser and had an indirect effect on the examinees' physical fitness.

Keywords: physical education, school age children, vestibular analyser, physical qualities.

INTRODUCTION

The modern requirements, imposed by the society on the children's health state and physical fitness, cause a need for a high-quality improvement of the physical education process in comprehensive educational institutions since it is an effective incentive for positive functional and morphological changes in the formed organism, and actively influences the development of motor abilities (Kryvoruchko, Masliak, Zhuravlyova, 2013; Maslyak, Mameshina, Zhuk, 2014; Bala, 2015; Aghyppo, Tkachov, Orlenko, 2016).

The most important question of the physical culture modern theory and practice is the improvement of the technique of pupils' physical education (Shesterova, 2003; Maslyak, 2006; Bala, 2015). It is caused by the fact that, between 7 to 15 years of age, first, the rapid development and formation of all the functions and systems of an organism occur, the major basic skills are formed, the base of a child's motor activity is created; secondly, school age children are very susceptible to various pedagogical, educational and training influences; thirdly, the foundation of practically all indicators of the adult physical fitness is laid at this stage of age development (Andreassi, 2000; Solodkov, Sologub, 2001; Smirnov, Dubrovskii, 2002).

According to many experts, the efficiency of the motor sphere formation process is, in many respects, defined by a functional condition of sensory systems: visual, acoustical, vestibular, tactile (Riemann, Lephart, 2002; Heekeren, Marrett, Bandettini, Ungerleider, 2004; Gold, Shadlen, 2007; Aghyppo, Kuzmenko, 2015).

One of the most important places in the course of training in movements and development of physical qualities is allocated to the vestibular analyser (Bundy, Lane, Murray, 2002; Geppert, Mailloux, Smith-Roley, 2004; Bear, Connors, Paradiso, 2007;

Rynkiewicz, Żurek, Rynkiewicz, Starosta, Nowak, Kitowska, Kos, 2010). As the vestibular sensory system is designed to analyse the provisions and the movements of the head and the body in space, it has an important role in managing motor activity. The vestibular mechanism preserves a person's body balance, it supports their posture, improves coordination of movements during rest and in the course of motor activities. The excessive irritation of the vestibular mechanism or heightened reactivity of the children's organism under high vestibular loadings can be one of the main barriers, which interferes in an all-round physical development (N. Sofiadis, E. Douda, O. Mertzanidu, N. Tsingilis, 1995; Horlings, Kung, Bloem, Honegger, Van Alfen, Van Engelen & Allum, 2008; Angelaki, & Cullen, 2008; Gaerlan, 2010).

Many authors dealt with issues of the separate analysers' influence on the pupils' motive sphere (Katukov, 2000; Rovnii, 2001; Smirnov, 2002; Maslyak, Shesterova, Terenteva, 2004; Kuzmenko, 2014).

A number of researches is devoted to studying the extent of the influence special physical exercises have on sensory systems' separate functions and the development level of physical qualities at various contingents: Moiseenko, 2013 – at children of preschool age, Maslyak, 2015 - at children of younger school age; Shesterova, 1998; Ivanova, 2001; Kuzmenko, 2014 – at children of middle school age; Pomeschikova, 2010 – at children with violations of musculoskeletal system; Magomedova, Shesterova, 2013 – at visually impaired children. At the same time, the question of vestibular analyser functions influence on the level of school age children's physical fitness remains insufficiently studied.

The purpose, work tasks, material and methods of the research

The purpose of this work – is to define the extent to which the pupils' (aged 7-15) level of physical fitness changes under the influence of the special exercises on the vestibular analyser.

Research methods: analysis of scientifically-methodical literature, pedagogical testing, methods of defining indicators of the vestibular sensory system separate functions, pedagogical experiments, methods of mathematical statistics.

Pedagogical testing assumed the use of motor skill tests to determine the development level of the main physical qualities. So, the extent of speed development was determined by results of a 30 m run for pupils 7-9 years old, 60 m – for pupils 10-15 years old (s); dexterity – by the results of a shuttle run 4×9 m (s); flexibility – trunk bending forward from a sitting position (sm); force – bending and extension of hands in lying support (a number of times), trunk lift exercises in a sitting position from a back-lying position (a number of times); endurance – by results of a 500 m run for pupils 7-9 years old, 1000 m – for pupils 10-15 years old (min., s).

The vestibular analyser resistance to rotational loadings was determined by deviation indicators, walking in a straight line on a 5 m piece (sm) while being blindfolded. The vestibular mechanism of examinees irritated with quintuple rotation to the right on the Barany chair with the head bent down and eyes closed. Rotation speed – 5 turns for 10 s. The results were determined, both before, and right after the vestibular irritation.

The researches were conducted on the basis of Kharkov comprehensive educational institutions. More than 800 pupils, out of whom 6 experimental and 6 control groups were made, took part in them: The first age group – 7 year old pupils, the second age group – 8 years old; the third – 9 years old (elementary school pupils); the fourth – 10-11 years old; the fifth – 12-13 years old; the sixth – 14-15 years old (middle school pupils).

All the children, participating in the research, were treated by the main and preparatory medical groups, and were observed by the school doctor.

Within the school year, the pupils of the control groups were engaged according to the standard state program for comprehensive educational institutions, and their physical education classes were supplemented with the specially selected physical exercises and outdoor games, which were oriented to activate the functions of the vestibular analyser: jumps with turns on 90 °, 180 ° and 360 ° with various starting positions of the head; running and walking with sudden stops; rotation around their own axis; fast bending of the head and trunks; performance of the listed exercises in the absence of visual control.

The special exercises were: performed in introductory, main and final parts of lesson; sports minutes were given at the lessons of general education subjects; implemented in the system of organized changes and offered in the form of homework. Besides, the main and final parts of lesson were supplemented with the modified outdoor games, and their content joined the listed exercises above.

The research results

The data acquired by the initial researches of the vestibular sensory system functional condition separate parameters allowed to establish the lack of reliable distinctions in indicators of pupils belonging to experimental and control groups ($p>0.05$). Considering the initial results in deviation when walking before and after vestibular loading took

part, it is established that the results of pupils, belonging all age groups, authentically worsened after the irritation of vestibular mechanism took place($p<0.05–0.001$).

The variable changes were observed in age aspect. Generally, the prevalence of the girls' over indicators of the boys' results was noted on a gender basis. The results of pupils belonging to the second and the third age groups made an exception, where the opposite tendency was observed.

The analysis of the results received after the experiment showed a considerable improvement in the stability of the vestibular analyser in pupils belonging to experimental groups. So, after the experiment, by comparing indicators before and after vestibular loading took place, it was revealed that after rotation, as well as before the experiment, the results of pupils belonging all age groups worsened. However, these changes are less essential (fig. 1). Comparing the results received before and after the experiment, after vestibular loading took place, it was revealed that indicators of vestibular stability in pupils belonging to all age groups significantly improved after the application of special exercises, and these distinctions, generally, have a reliable character ($p<0.01$-0.001). It demonstrates the positive influence the experimental program had on practicing the school physical education. So, the obtained results on deviation indicators from walking in a straight line after vestibular loading took place are: boys from the first group had – 64.4%; the second group – 55.1%; the third – 74.1%; the fourth – 70.3%; the fifth – 70.6%; sixth – 72.6; and girls had 46.5%; 65.2%; 71.9%; 67.7%; 68.8%; 70.7% respectively. Thus, the most essential changes of indicators can be seen both in boys, and girls who are 9 and 14-15 years old.

The analysis of the studied control groups' vestibular stability indicators received after the experiment demonstrates that they also underwent some changes. However, these changes are neither essential nor reliable ($p>0.05$) (fig. 2).

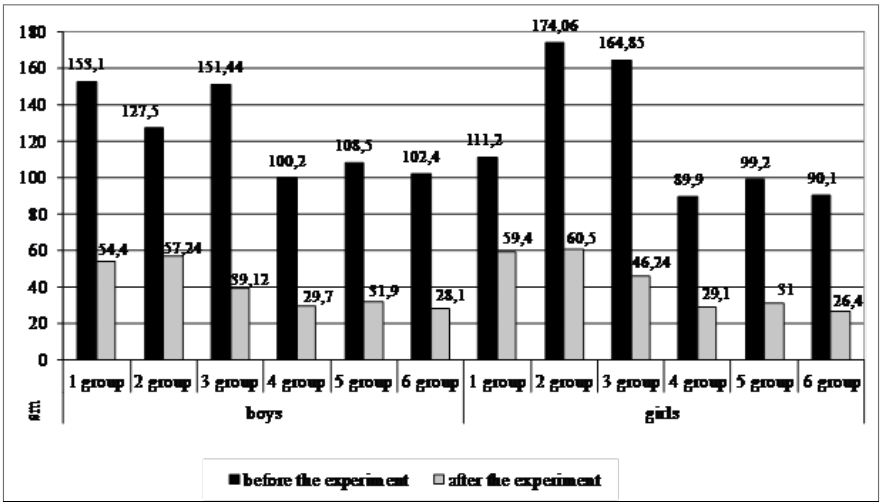

Fig. 1. Deviation indicators from walking in a straight line after vestibular loading of pupils belonging to experimental groups took place, before and after the experiment

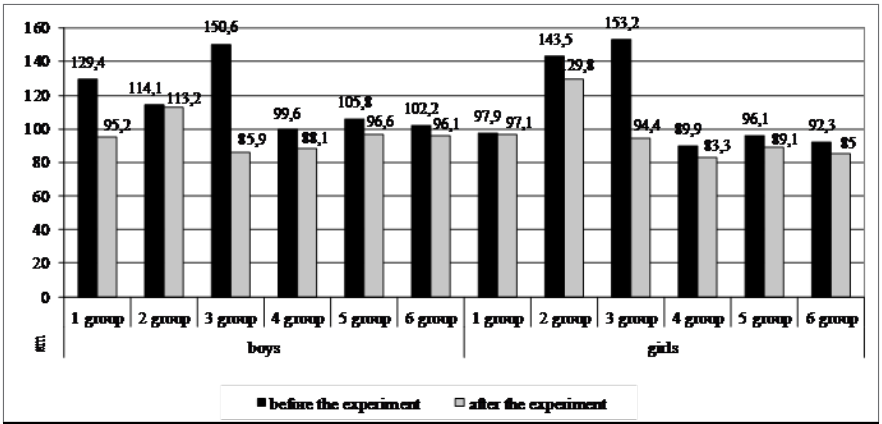

Fig. 2. Deviation indicators from walking in a straight line after vestibular load loading of pupils belonging to experimental groups took place, before and after the experiment

Essential changes, in comparison with the initial research on pupils from experimental, and control groups, were not revealed in age and sexual aspects. Thus, the introduction of a special exercises system in the physical education classes, which are oriented to increase vestibular stability, positively affected the functional condition of the vestibular analyser both in boys, and girls belonging to all age groups. The indicators of pupils 9 and 14-15 years old improved most significantly. The use of the offered system of exercises positively affected not only the sensory systems functional condition, but also the examinees' physical fitness. So, the gained indicators of the speed development level in boys of the first group were 9.3%; the second group – 10.4%; the third – 13.6%; the fourth – 7.9%; the fifth – 7.8%; the sixth – 5.8%; and the girls had 7.9%; 12.3%; 12.8%; 7.3%; 7.8%; 4.8% respectively; the gained indicators of the of dexterity development level in boys of the first group were 6.9%; the second – 7.7%; the third – 8.3%; the fourth – 9.4%; the fifth – 8.0%; the sixth – 5.5%; and the girls had 6.2%; 6.4%; 7.0%; 8.6%; 6.7%; 6.1% respectively; the gained indicators of the flexibility development level in boys of the first group were 22.6%; the second group – 13.5%; the third – 11.2%; the fourth – 14.9%; the fifth – 34.2%; the sixth – 29.8%; and girls had 6.3%; 5.9%; 6.6%; 53.4%; 28.9%; 21.7% respectively; the gained indicators of the hands muscular strength development level in boys of the first group were 5.8%; the second – 4.0%; the third – 3.8%; the fourth – 25.7%; the fifth – 14.9%; the sixth – 6.3%; and the girls had 12.7%; 10.6%; 8.2%; 22.6%; 14.8%; 19.9% respectively; indicators of the prelum abdominale muscular strength development level in boys of the first age group improved by 8%; the second – by 2.7%; the third – 5.7%; the fourth – 6.8%; the fifth – 10.7%; the sixth – 7.9%; and in girls – by 7.3%; 4.9%; 3.6%; 17.6%, 7.6%, 11.8% respectively. Indicators of the elementary school pupils' endurance development level didn't practically change, and the gain in the fourth group was 7.1% in middle school boys the gain in the fifth group was 4.1%; in the sixth – 5.2%; girls had 6.3%; 4.9%; 3.8% respectively.

Changes in the indicators of physical fitness level are less essential and had, as a rule, a natural character in examinees from control groups.

By analysing the change of indicators in age aspect, it is established that the most essential changes are recorded in speed indicators for 7 year old boys, for girls of the similar age – in prelum abdominale muscular strength indicators; the most considerable changes happened in flexibility indicators for 8 year old boys, for girls – in manifestations of speed and muscular strength of the prelum abdominale; the most essential changes are recorded in indicators of speed, dexterity, muscular strength of hands and prelum abdominale for 9 year old boys, for girls - in flexibility indicators; the most significant changes in indicators of high-speed abilities, endurance, dexterity and muscular strength of hands were observed in 11 year old boys, indicators of endurance, dexterity, flexibility, muscular strength of hands and prelum abdominale improved most significantly for girls of this age. The substantial increase in indicators of prelum abdominale muscular strength, and flexibility was observed in boys at the age of 12-13, high-speed abilities were observed in girls. The less significant rates of the gain in motor skills preparedness indicators were noted both in boys and girls at the age of 14-15.

THE COMPARISON OF RESULTS OBTAINED FOR BOYS AND GIRLS ALLOWS US TO SAY THAT THE DEVELOPMENT OF MOTOR ABILITIES IN BOYS, AND GIRLS FROM ALL AGE GROUPS IS MORE SUSCEPTIBLE TO THE IMPACT OF THE SPECIALLY ORIENTED EXERCISES AT HIGHER ABSOLUTE MEASURES.

The correlation analysis was carried out for the purpose of defining the extent of the influence of the vestibular analyser functional condition on the level of 7-15 years old pupils' physical fitness.

The obtained data confirm the existence of interrelation between vestibular sensory system parameters and the development level of the pupils' motor abilities, which is reflected, generally, in "average" interrelation degree, on size (the coefficient of correlation varied ranging from 0.21 to 0.57 at $p<0.05$-0.01). So, the coefficient of correlation varied ranging from 0.33 to 0.55, at $p<0.05$-0.01; dexterity – from 0.33 to 0.57, at $p<0.01$; endurance – from 0.21 to 0.39, at $p<0.05$; forces – from 0.20-0.54, at $p<0.05$; flexibility from 0.20 to 0.48, at $p<0.05$-0.01 between the indicators of the vestibular analyser and the speed development level.

The tendency of interrelation remained also at the repeated research, and even the increase in degree of dependence to "strong" on size was in some cases noted. The essential increase in interrelation was noted between the vestibular sensory system parameters, the speed development level and dexterity ($r=0.75$; $r=0.81$ respectively). It is revealed that interference of the studied parameters depends on age and, in some cases, on sex.

Thus, the correlation analysis of the data obtained in the end of the experiment demonstrates that the extent of interference of the vestibular analyser functional condition indicators and the separate physical qualities development level considerably improved after the application of the specially oriented exercises. It should be noted that the interrelation degree of the studied parameters increased with age.

DISCUSSION

According to experts, the optimum level of an organism's functional condition is provided with a perfect vestibular sensory system function. It plays an important role in a person's spatial orientation, receives, transfers and analyses information on the accelerations or delays, arising in the course of performance of the movement and also in the change of the head position in space (N. Sofiadis, E. Douda, O. Mertzanidu, N. Tsingilis, 1995; Horlings, Kung, Bloem, Honegger, Van Alfen, Van Engelen & Allum, 2008; Angelaki, & Cullen, 2008; Gaerlan, 2010).
Considering the indicators of the vestibular analyser functional condition, it should be noted that they improved authentically in pupils of all experimental groups after the application of special exercises ($p<0.01$-0.001). It confirms the data of a number of researchers on positive impact of the specially oriented exercises on improvement of the vestibular analyser functional condition (Kiryalanis, Laparidis, Sofiadis, 2002; Senicya, 2004; Nazarenko, Chehalin, 2004). In our opinion, it is connected with the fact that proprioceptive impulses, interacting with vestibular, subordinate them to the influence and slow down manifestation of vestibular reflexes, providing thereby the best solution of the motor task.
The most considerable gain of results was observed in pupils 9 and 14-15 years old. Results of the research confirm the opinion of Solodkov, Sologub, 2001, who consider that the vestibular sensory system ripens by the age of 14. The analysis of vestibular irritations is improved with a child's age, and excitability of vestibular sensory system decreases that reduces manifestations of collateral motor and vegetative reactions.
By analysing indicators of vestibular analyser stability before and after rotary loadings, it should be noted the deterioration in results in bipedalism, both in boys, and in girls, that will be coordinated with the researches' data of such authors as Maslyak, Shesterova, Terenteva, 2004; Kuzmenko, 2015, etc. Asymmetry during walking is explained by the fact that information which arrives from receptors of the motor skills' apparatus of the lower extremities especially from ankle joints of the right and left legs, is insufficiently accurately perceived and analysed, and does not give in to the careful comparison. Only with age (especially in conditions of sports activities) when special attention is paid to the correct placement of a leg on soil, the necessary degree of comparison of feet turning signals is reached.
The analysis of the repeated researches' results, which were received after the application of the special exercises, which positively affected the vestibular touch system functional condition, has allowed revealing some changes which have happened in indicators of the physical qualities development level.

SO, THE SPEED DEVELOPMENT LEVEL OF PUPILS BELONGING TO EXPERIMENTAL GROUPS OF ALL AGE INCREASED CONSIDERABLY AND AUTHENTICALLY (?<0,001). IN OUR OPINION, IT IS EXPLAINED BY THE EXISTENCE OF A RATHER CLOSE INTERRELATION BETWEEN THE MANIFESTATION OF SPEED AND THE VESTIBULAR ANALYSER FUNCTIONAL CONDITION (SAPIN, M.R. & SIVOGLAZOV, 2002).

By analysing the repeated indicators of the dexterity development level, it is revealed that they improved considerably and authentically for pupils belonging to experimental groups, both boys, and girls ($p<0.05$-0.001). In our opinion, their gain is explained by a rather high degree of dependence of dexterity manifestation on functionality of the studied sensory system (Krucevich, 2012). Flexibility indicators for pupils belonging to experimental groups of all age improved authentically owing to the experiment ($p<0.05$-0.001). In our opinion, the gain of indicators of this quality is explained by the existence of certain correlation interrelation between separate parameters of vestibular sensory system and the indicators of flexibility. By analysing the change of the force development level owing to the application of the specially oriented exercises, which are positively influencing the indicators of the studied analyser functional condition, it is revealed that they improved authentically for pupils belonging to experimental groups ($p<0.05$-0.001). Their gain, in our opinion, is explained by the correlation dependence between the vestibular analyser parameters and force indicators, and also the existence of a rather close interrelation between the manifestation of power, coordination and high-speed abilities (Volkov, 2002; Nazarenko, 2003; Krucevich, 2012) That is, the gain of indicators of dexterity and speed development

causes an increase in the force development level and vice versa. Considering the repeated indicators of the endurance development level, it is defined that they improved for pupils belonging to experimental groups of all age. However, the recorded changes have a reliable character only in indicators of middle school pupils ($p<0.001$). The endurance development has a natural character in elementary school pupils. It confirms the opinion of a number of authors (Shiyan, Papusha, 2000; Volkov, 2002) who note that the manifestation of endurance is caused by the functional condition of cardiovascular and respiratory systems, which are insufficiently developed at a younger school age.

CONCLUSIONS

1. The Data collected by the initial researches confirm the insufficient stability level of the vestibular analyser that was confirmed by the considerable and reliable deterioration in indicators after rotary loading took place in all age groups.

2. The application of the specially oriented exercises in the course of physical education positively affected the vestibular sensory system functional condition of pupils belonging to experimental groups ($p<0.05$–0.001). The most susceptible periods for vestibular analyser training of elementary school pupils is the age 9; of middle school pupils is the age of 14-15. The control groups' pupils' results did not change significantly and authentically.

3. The researches of the physical fitness level after the use of a specially oriented exercises system demonstrate a reliable improvement in pupils belonging to experimental groups of the physical qualities development level ($p<0.05$-0.01). An exception is made by indicators of 7-9 years old pupils' endurance which practically didn't change. The data on pupils belonging to control groups didn't undergo essential changes.

4. The correlation analysis of the vestibular analyser functional condition and the physical qualities development level indicators confirms the existence of a rather close interrelation between them that gives the grounds to speak about a rather high extent of interference of these parameters ($r=0.33$-0.81).

Further researches in this direction can be conducted by defining the extent of the influence of the separate sensory functions activity level on motor skills preparedness of the senior classes' pupils.

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Conflict of interests

The authors declare that there is no conflict of interests.

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UTJECAJ FUNKCIONALNOG STANJA VESTIBULARNOG APARATA NA FIZIČKE SPOSOBNOSTI ŠKOLSKE DJECE

Svrha: definirati opseg promjena razine fizičke spremnosti učenika 7-15 godina pod utjecajem posebnih vježbi, utjecajem na vestibularni aparat. Materijal: istraživanja su provedena na bazi obrazovnih institucija Kharkov-a. Ispitano je više od 800 učenika, od kojih su izrađene 6 eksperimentalnih i 6 kontrolnih skupina. Rezultati: ispitivani su funkcionalno stanje vestibularnog aparata i razina fizičke spremnosti učenika; uzete su u obzir razlike istraživanih pokazatelja u dobnim i spolnim aspektima; Povezanost otpornosti vestibularnog senzornog sustava na rotacijska opterećenja i definirane su razine razvoja fizičkih osobina učenika; utvrđen je opseg utjecaja posebno orijentiranih vježbi na funkcionalno stanje vestibularnog aparata i fizičke sposobnosti ispitanika. Zaključci: 1. Kao posljedica početnih istraživanja je ustanovljena nedovoljna razina otpora vestibularnog aparata u rotacijskim opterećenjima. 2. Analiza korelacija pokazala je postojanje prilično uske međusobne povezanosti funkcionalnog stanja vestibularnog aparata i stupnja razvoja fizičkih osobina. 3. Primjena posebno odabranih vježbi pozitivno je utjecala na funkcionalno stanje vestibularnog aparata i posredno na fizičke sposobnosti ispitanika. Ključne riječi: tjelesni odgoj, djeca školske dobi, vestibularni aparat, fizičke sposobnosti.

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