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The Effect of Physical Exercises and Ball Games on the Static Balance of Students with Musculoskeletal Disorders

Oleksandr Aghyppo[1], Irina Pomeshchikova[2], Ludmila Filenko[3], Vladlena Pasko[3], Romana Sirenko[4] and Oleksandr Poproshaiev[5]

[1]Kharkiv State Academy of Physical Culture, Department of Theory and Methods of Physical Education, Kharkiv, Ukraine, [2]Kharkiv State Academy of Physical Culture, Department of Sports and Outdoor Games, Kharkiv, Ukraine, [3]Kharkiv State Academy of Physical Culture, Department of Computer Science and Biomechanics, Kharkiv, Ukraine, [4]Ivan Franko Lviv National University, Head of the Department of Physical Education and Sports, Lviv, Ukraine, [5]Yaroslav Mudryi National Law University, Department of Physical Education No. 1, Kharkiv, Ukraine

Abstract

This research aims to detect the effect of using exercises and ball games in physical education on the static balance of students with musculoskeletal disorders. The research involved 40 secondary school students aged 16-19, who were divided into two groups. Students have disabilities with mild and average forms of illness. The level of static balance was determined by the indicators of a modified Romberg test, which was carried out at the beginning and the end of the training lesson. The research was carried out for 18 months. It was established that the indicators of students of two groups, both at the beginning and at the end of the physical education lesson, improved. At the beginning of the lesson, a reliable change is traced only in the group of students with congenital defects of the musculoskeletal system ($p<0.05$); at the end of the lesson, balance indicators significantly improved in both groups ($p<0.05$). It was found that the developed system of exercises and ball games in which it was necessary to keep a set initial position, not due to different actions with the ball, is an effective means of improving balance. Exercising and playing with the ball reliably (at the level of significance $\alpha=0.05$) increases the chance of students to improve static balance indicators, which can improve the quality of motor actions in everyday life. The inclusion of specially selected exercises and ball games in physical education classes for students with musculoskeletal defects related to the success of meeting the requirements of Romberg's test is statistically confirmed.

Keywords: *students, musculoskeletal system, physical education, balance, Romberg's test, exercises with the ball*

Introduction

The process of physical education in special educational institutions for students with disabilities is one of the components of their social adaptation; this applies to students with impairment of the musculoskeletal system (Druz, Klimenko, & Pomeshchikova, 2010). Maintaining stable balance and normal support ability and preserving them in different situations is acute for this category of students. Doing so provides them with relative freedom of movement and a rational rhythm of motor actions, which are important for their better adaptation to life conditions (Pomeschikova & Terent'eva, 2010; Pomeshchikova et al., 2017).

The problem of physical and social adaptation of people with musculoskeletal disorders has been considered by many specialists in the following development areas: psychological adaptation (Razuvaieva et al., 2019), wellness programs

Correspondence:

I. Pomeshchikova
Kharkiv State Academy of Physical Culture, Department of Computer Science and Biomechanics, Klochkovska str. 99, Kharkiv, 61058, Ukraine
E-mail: i.pomeshikova@khdafk.com

(Araújo, Starling, Oliveira, Gontijo, & Mancini, 2020), and training athletes with musculoskeletal disorders (Mishyn et al., 2018). The authors raised the possibility of social rehabilitation and improving the level of comfort life of people with musculoskeletal disorders using physical exercises of different orientations.

Balance is one of the main motor coordination qualities, the level of development of which can fully serve as an indicator of motor abilities (Bretz, 1997). According to Davletiarova and Kapilevich (2012), a decrease in the persistence of the vertical pose (disruption of balance function) is one of the leading problems accompanying motor disorders of different aetiologies. Impaired balance function significantly increases the possibility of falls, both when standing and walking, and increases the risk of injuries. Therefore, the formation of balance in persons with disorders of the musculoskeletal system is an important element for their better adaptation to life conditions (Pomeshchikova & Terentieva, 2010; Bretz, 1997). Researchers have used different means of physical education to improve coordination abilities: exercises on specially designed gym devices (Hagberg, Hermansson, Fredriksson, & Pettersson, 2015), equine therapy (Silkwood-Sherer et al., 2012), among others. However, exercises and ball games have yet to find wide application in the physical education of students with musculoskeletal disorders. At the same time, significant interest of children and adolescents in ball sports can be noted (Ashanin et al., 2018; Bykova et al., 2017). Students' diverse motor activity during the ball game is accompanied by positive emotions and increases interest in exercising.

The contribution of this research is to increase the efficiency of physical education classes with students who have musculoskeletal disorders in order to restore their balance function.

Methods

The research involved 40 students with musculoskeletal disorders (16–19 years old, girls and boys) who studied at Accounting and Economic College-Boarding School in Kharkiv. The students with mild and average levels of disability. All students were under the supervision of a doctor and did not have contraindications to physical education. Agreements were obtained from all participants to participate in the pedagogical experiment.

Students were divided into two groups to determine the effectiveness of using exercises and ball games in physical education classes. The first group included students who have congenital diseases that led to musculoskeletal disorders. The second group – students at which musculoskeletal disorders arose as a result of injuries and diseases throughout their lives. Among them 60% (24 students) have congenital defects, 40% (16 students) acquired. The information about diseases and pathologies of students was obtained due to the analysis of doctors' remarks in medical records.

Students of both groups were engaged in the adjusted program of physical education of special educational institutions during three semesters. The lesson lasted 90 minutes and were of average intensity. Classes were held twice a week. The content of physical education classes (simultaneously with the programme's educational material) included exercises and ball games, aimed at developing static resistance. These exercises were performed in the initial position, standing with legs together; standing on the heel of one foot and on the toe of the other. When they were carried out, the tasks were performed on one position and, as a more difficult option, with closed eyes. These include exercises such as placing the ball from hand to hand around the neck and torso; raising the ball over oneself and catching it; dribbling balls on the floor. Basketballs, volleyballs, and tennis balls were used. Exercises were performed either for a time from 6 to 10 s, or with a dosage from 1-2 to 3-4 times, using from 1 to 3 series, rest pauses lasted 20-40 s. The exercises took into account individual features of students' health. Examples of exercises with balls aimed at the development of static balance have been presented previously (Pomeshchikova et al., 2017; Table 1).

Exercises with balls were included in the content of moving games such as "Duel", "Gentle Ball", "Running on bumps", relay races with balls, dribbling in space limited by the conditions of the assignment, but others. At the same time, the conditions of the game constantly changed (Pomeschikova, 2010).

The research was carried out in compliance with the basic bioethical provisions of the Council of Europe Convention on Human Rights and Biomedicine (dated 04.04.1997).

The level of students' static balance was determined by the indicators of modified Romberg's test. The student putting his feet on one line (the toe of the right leg is near the heel of the left leg) stood, holding his balance. Standing in the position of the hand along the torso less than 15 s, the tested person received 1 point, standing in this position 15 s, received 2 points. Extending his hands forward and standing another 15 s – 3 points, closing his eyes and standing another 15 s – 4 points, raising his head with his eyes closed up and standing another 15 s in the same position – 5 points (Ilyin, 1981). With 3-5 points – the score was "passed", with 1-2 points – "didn't pass". The assessment of static balance was carried out at the beginning and the end of the physical education lesson of medium intensity.

The statistical data were analysed using STATISTICA version 10 and Excel 2016 spreadsheets. The test of statistical hypotheses about the belonging of the studied sample of students of the general population and the validity of differences in indicators at the beginning and the end of the pedagogical experiment was performed using Student's t-test was considered to be reliable at $p<0.05$.

In the research, the qualitative performance indicators of Romberg's test were studied to establish the presence (X_1) of static balance at the studied, which have a deviation of a congenital (Y_0) character and acquired during life (Y_1). To establish relationships between qualitative features at study factors X and Y, the contingent coefficient was calculated ($K_k=\varphi$):

$$\varphi = \frac{ad - bc}{\sqrt{(a+b)(c+d)(a+c)(b+d)}}$$

and associations ($K_a=\zeta$):

$$\zeta = \frac{ad - bc}{ad + bc}$$

If the contingent coefficient ($K_k=\varphi$) is less than the association coefficient ($K_a=\zeta$), this indicates the presence of a relationship between the two factors studied: static balance (X) and deviation in physical health (Y).

Pearson criterion χ^2 was applied to test the hypothesis that there was a relationship between the studied factors:

$$\chi^2 = \varphi^2 \cdot n.$$

Pearson's estimated value was compared to Pearson's table

Table 1. Ball exercises aimed at developing static balance

	Exercise content	Dosage
1.	in the initial position, standing feet together, shifting a basketball (volleyball) ball from hand to hand around you: - at the neck level; - at the waist level; - at the knee level ; (one and then the other)	6-8 times, 1-2 repetitions, rest between 10-20 s series
	also, in the initial position, standing, heel of one leg - toe of the other	4-6 times, 1-2 repetition, rest between series 10-20 s
	also with closed eyes	2-4 times, 1-2 repetitions, rest between 10-20 s series
2.	- in the initial position, standing legs together, tossing a basketball (volleyball) ball with two (one) hands up and catching it without leaving the place	4-6 times, 2-3 repetitions, rest between 20-30 s series
	also, in the initial position, standing heel of one leg - toe of the other	3-4 times, 1-2 repetitions, rest between 20-30 s series
	also with closed eyes	2-3 times, 1-2 repetitions, rest between series 30-40 s
3.	- in the initial position, standing feet together dribbling a basketball ball in front of oneself, alternately with left - right hand (from hand to hand), putting a hand on a ball from the side outside and hitting the ball on the floor in front of oneself in the same place	8-10 s, 1-2 repetitions, rest between 20-30 s series
	also with closed eyes	6-8 s, 1-2 repetitions, rest between series 30-40 s
4.	- in the initial position, standing heel of one leg - toe of the other, dribbling the basketball ball with one hand forward - backward (putting a hand on a ball in turn in front - behind) and hitting the ball on the floor in one and the same	8-10 s, 1-2 repetitions, rest between 20-30 s series
	also with closed eyes	6-8 s, 1-2 repetitions, rest between series 30-40 s
5.	- in the initial position, standing feet together, a tennis ball is in one hand, tube for storing tennis balls is in the second; lobbing a tennis ball and catching it in a tube without moving out of place	3-4 times, 2-3 series, rest between repetitions 20-30 s
	also, in the initial position, standing heel of one leg - toe of the other	2-3 times, 1-2 repetitions, rest between series 30-40 s
	- in the initial position, standing feet together, a tennis ball is in one hand, tube for storing tennis balls is in the second; hitting the ball in the floor and after bouncing the ball catching it in a tube without going out of place	3-4 times, 2-3 series, rest between repetitions 20-30 s
	also, in the initial position, standing heel of one leg - toe of the other	2-3 times, 1-2 repetitions, rest between series 30-40 s

χ^2_α with the number of degrees of freedom ν=1. There is a lack of dependence between the studied indicators for conditions $\chi^2<\chi^2_\alpha$. If $\chi^2>\chi^2_\alpha$, this indicates the presence of a statistical relationship between the qualitative studied indicators. The research applied a two-sided criterion, which is determined by the number of degrees of freedom ν=1 as $\chi^2_{0.05}$=3,84; $\chi^2_{0.01}$ = 6,63 and $\chi^2_{0.001}$=10,83 (Lupandin, 2009).

The study objects were classified according to several nominal characteristics: Romberg's test before physical education classes and after it, at the beginning of the research, and during re-examination after the introduction of the corrective technique.

Results

An analysis of the obtained indicators of Romberg's test before the pedagogical experiment noted the highest indicators of static balance, both at the beginning and at the end of the lesson in the first group of students (who have diseases and disorders of the musculoskeletal system acquired during life), but the differences were not reliable (p>0.05; Table 2).

It should be noted that the results of testing students

Table 2. The analysis of Romberg's test at the beginning and at the end of the research

Studied	Romberg's test at the beginning of classes		t	p	Romberg's test at the end of the classes		t	p
	Before the experiment	After the experiment			Before the experiment	After the experiment		
Group 1	2.88±0.38	3.75±0.25	1.94	>0.05	2.56±0.36	3.88±0.26	2.94	<0.05
Group 2	3.00±0,28	4.04±0.20	2.99	<0.05	2.96±0.30	4.29±0.15	3.91	<0.05
t	0.25	0.91			0.85	1.37		
p	>0.05	>0.05			>0.05	>0.05		

Legend: Group 1 - Students with lifetime acquired diseases (Y_1) (n=16); Group 2 - Students with congenital diseases (Y_0) (n=24)

with musculoskeletal disorders are much lower than those of healthy people.

When studying data obtained after the use of specially directed exercises and ball games that affect the ability to maintain static balance, it was found that indicators of the students of two groups improved, both at the beginning and at the end of the physical education lesson, but these changes were not always reliable (Figure 1). For example, at the beginning of the lesson, a reliable change is traced only in the group of students with congenital defects of the musculoskeletal system ($p<0.05$), while at the end of the lesson, balance indicators significantly improved in both groups ($p<0.05$).

Between the selected groups, indicators are slightly better noted, both at the beginning and end of the physical education lesson, among students with congenital musculoskeletal system defects, although there are no reliable differences ($p>0.05$).

The improvement in Romberg's test at the beginning of the lesson in the group of students with congenital muscu-

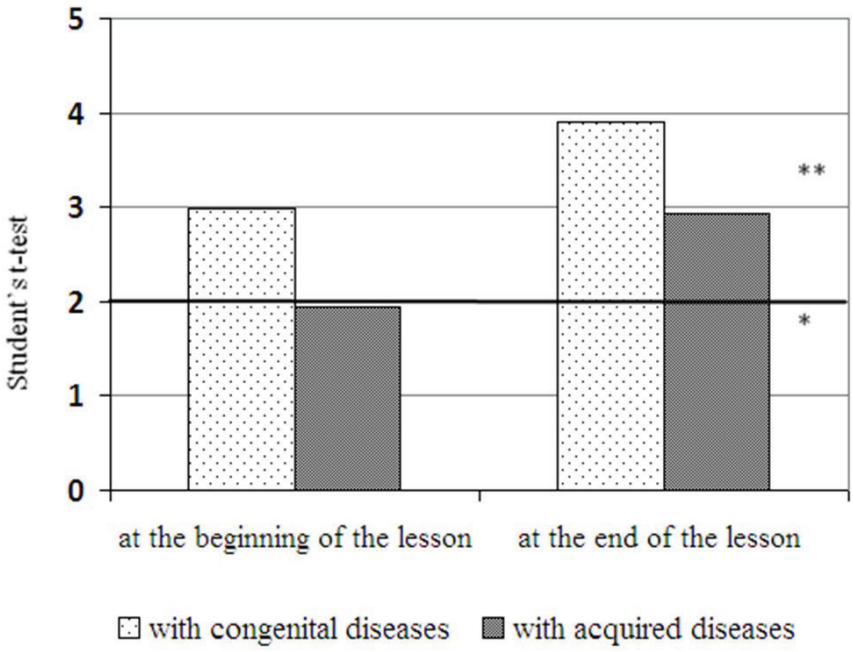

FIGURE 1. The validity of changes in statistical balance indicators on the student's criterion at the beginning and at the end of the physical education lesson (Student's t-test limit for n=40 is t_{limit}=2.01 (Lupandin, 2009), **– reliable differences ($p<0.05$); *– lack of reliable differences ($p>0.05$)

loskeletal defects amounted to 1.04 points; in the group with acquired musculoskeletal disorders, 0.87 points; at the end of the lesson, 1.33 and 1.32 points, respectively, according to Table 3.

The research results on the qualitative level of balance development are presented in the form of tables of ratios. In

Table 3. Changes in performance in Romberg's test under the influence of ball exercises and games

Studied	Romberg's test at the beginning of classes		Romberg's test at the end of the classes	
	points	%	points	%
Group 1	0.87	17.4	1.32	26.4
Group 2	1.04	20.8	1.33	26.6

Table 4, the lines indicate the disease group (Y_1 – acquired during life and Y_0 – congenital), and the columns indicate the result of Romberg's test (the presence of static balance – X_1 and its absence – X_0). In response to the presented table, we highlight two factors of one phenomenon.

Calculation of the contingent coefficient (K_k=φ=0.33) and the association coefficient (K_a=ζ=0.60) and their comparison indicates the presence of dependence between the two balance factors (X) and a deviation in the physical health of the studied students (Y), both before the lesson and after the lesson

Table 4. Dichotomous table for finding balance (X) ratio in students with musculoskeletal disorders (Y) at the beginning of the research

Group of diseases	The result of Romberg's test before the lesson		Total Σ=	The result of Romberg's test after the lesson	
	passed (X_1)	didn't pass (X_0)		passed (X_1)	didn't pass (X_0)
Acquired during life (Y_1)	a=17	b=7	24	a=16	b=8
Congenital (Y_0)	c=6	d=10	16	c=5	d=11
Total Σ=	23	17		21	19

(K_k=φ=0.35 and K_a=ζ=0.63).

Pearson's value χ^2 both before the lesson =6.55; and after the lesson =7.24 indicates the presence of a relationship with validity p=0.95, at the significance level α=0.05. The criterion value φ=0.33 and φ=0.35 with the number of studied n=40 (according to Lupandina, 2009) is interpreted as a relatively strong relationship between nominal variables at the significance level α=0.05.

Under the influence of the developed method of the structure of educational classes on physical education, students with health defects improved balance indicators (Table 5), both students with acquired defects of the musculoskeletal system during life and adolescents with congenital defects of the musculoskeletal system. The score "didn't pass" disappeared from the two examined groups.

At the end of the physical education lesson, the balance indicator "passed" appeared in almost all students. The score "didn't pass" was observed only in one student with acquired defects of the musculoskeletal system during life in four students with congenital defects of the musculoskeletal system.

The obtained results of the analysis of the indicators of the ratio of the examined factors X and Y and the calculation of the contingent coefficients (before the lesson K_k=φ=0.31 and after the lesson K_k=φ=0.31) and association (before the lesson K_a=ζ=0.58 and after the lesson K_a=ζ=0.77) indicate the presence of a close dependence, the contingent coefficient is less than the association coefficient (K_k=φ<K_a=ζ before the physical education lesson and after it). Pearson's calculation figure χ^2, both before the class (χ^2=5.58) and after the class (χ^2=5.71) exceeds the critical value with the number of freedom degrees ν=1 $\chi^2_{0.05}$=3.84.

Table 5. Dichotomous table for finding balance (X) ratio in students with musculoskeletal disorders (Y) at the end of the research

Group of diseases	The result of Romberg's test before the lesson		Total Σ=	The result of Romberg's test after the lesson	
	passed (X_1)	didn't pass (X_0)		passed (X_1)	didn't pass (X_0)
Acquired during life (Y_1)	a=19	b=5	24	a=23	b=1
Congenital (Y_0)	c=8	d=8	16	c=12	d=4
Total Σ=	27	13		35	5

The use of non-standard methods of mathematical statistics in the research of qualitative and nominal balance indicators in students with defects in the musculoskeletal system contributed to the improvement of methods for the structure of educational classes.

By calculating Pearson's test χ^2 and its alternatives, it was statistically confirmed that the choice of physical exercises and ball games to develop balance correlates and is associated with musculoskeletal disorders of students. From a practical point of view, there must be a relationship between the analysed qualitative indicators and when estimating the degree of connection between them at the level of significance α=0.05.

Discussion

For the results of Student's t-test, Pearson's criterion χ^2, the contingent coefficient and association obtained in the research, the effectiveness of the influence of motor activity using ball exercises in physical education classes on the static balance of students with musculoskeletal disorders can be argued. The level of 17.4–26.6% showed that we established the influence of exercises and outdoor games with balls on improving balance indicators in students with disabilities. Our research supports the results of other authors (Gutierrez & García-López, 2012; Hastie & André, 2012), which point to the positive impact of gaming actions on students' physical fitness indicators. Thus, it is possible to recommend ball exercises and games to improve the process of physical education of students with musculoskeletal disorders. It should be noted that ball exercises and games increase the psycho-emotional background of the class, are attractive for students and are performed with satisfaction, as evidenced by the work of Fink, Stagnitti, and Galvin (2012) and Hastie and André (2012).

Using the statistical analysis of the research of qualitative indicators of each student individually provided an opportunity to take into account the physical state depending on the defect of the musculoskeletal system, which also contributed to a more accurate selection of the initial position of the exercises, the conditions for their performance, and dosing. The results of our research continue and correlate with the work of Aurora (2014) in improving the physical education of people with disabilities. This is consistent with the data of Kashuba and Zharova (2006), which noted the improvement in vertical resistance parameters in patients with orthopaedic pathology after the use of special physical exercises.

In summation, the balance state of students with musculoskeletal disorders is improved under the influence of the proposed means, namely ball exercises and games. When applying the proposed technique, it is possible to reproduce the individual trajectory of exercise, which allows students to be active in the lesson. Increasing balance indicators will improve people's quality of life with defects in the musculoskeletal system. The same conclusions are reached in the research of Martino et al. (2019), Pomeshchikova et al., (2016), and Salter (1999).

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Conflict of interest
The authors declare that there are no conflicts of interest.

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Conclusions

Exercising and playing with balls reliably increases (at the level of significance α=0.05) the possibility of students to improve static balance indicators in a modified Romberg's test.

Using the calculation of criterion χ2, we statistically confirmed that the inclusion of specially selected exercises and ball games in physical education lessons for students with musculoskeletal disorders related to the performance of meeting the requirements of test exercises aimed at assessing the balance indicator.

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