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Original research article

THE EFFECTS OF AN ERGONOMIC EXERCISE PROGRAM WITH A PILATES BALL ON REDUCING THE RISK OF THE INCIDENCE OF MUSCULOSKELETAL DISORDERS

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Abstract. *Introduction: Very few scientists have studied the influence of rehabilitation exercises on reducing the risks of musculo-skeletal disorder incidence (MSD). Therefore, it is necessary to study the influence of these exercise programs on the prevention of and decrease in the risk of MSD development among schoolchildren. A special ergonomic program is based on the education of schoolchildren on ergonomic risks and their prevention by means of specific exercises with a Pilates ball for each recognized MSD, with the assumption that its sixteen-week application will significantly influence the risk of MSD incidence. Methods: The overall sample consisted of 55 students whose chronological age was 11, of both sexes, who were divided into two sub-samples: the experimental group (EG) of 28 students and the control group (CG) of 27 students. The Spinal Mouse and the appropriate program support was used for the evaluation of muscular-skeletal disorders of the spine in the sagittal and frontal parts (kyphosis, lordosis, thoracic scoliosis). Results and Discussion: The results, following the experimental program, have shown significantly lowered values of the kyphotic and thoracic scoliotic curve in the experimental group (EG), whereas the condition of the control group (CG) deteriorated, however, not with any statistical significance. As for lordosis, there were no significant changes in either group during the experimental treatment. A variance analysis showed that exercises with a Pilates ball program had statistically significant effects on decreasing MSDs with kyphotic and thoracic scoliotic curves but with no significant effects on lordosis as*

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compared to the school exercise program. Conclusion: The conclusion drawn from the analysis of the effects of the specially defined ergonomic program, in the form of specific exercises with a Pilates ball, is that it leads to reducing the risk of MSDs incidence among fourth-grade elementary school students. The experimental actions applied showed to have a positive influence on lowering the spine MSDs in the case of the experimental group, but there were no significant changes in the case of the control group.

Key words: *musculo-skeletal disorder, ergonomics, students, Pilates ball, exercises program effects.*

INTRODUCTION

A very high MSD incidence was noted during regular examinations of schoolchildren in Serbia every year. Previous studies have shown that its occurrence among children and adolescents is within the range of 63% and 83% (Živković, 1992). In addition, former research (both in our country and abroad) has shown that children spend more than 7 hours a day sitting at their school desks or at their computers at home. During that time their body posture is often influenced by the characteristics of everyday furniture. Ordinary furniture used both at school and at home does not meet the adults' and children's needs and abilities.

The main consequence of the ergonomic mismatch is bad sitting body postures (Feathers, Pavlović-Veselinović & Hedge, 2013; Ehrmann-Feldman, Rossignol & Abenhaim, 2002). When children of different ages and height sit on chairs that cannot be adjusted, a high percentage of them is likely to develop sitting posture problems (Marshall, Harrington & Steele, 1995). As a result, bodily bio-mechanical stress will increase (Panagiotopoulou, Christoulas, Papanckolaou & Mandroukas, 2004; Parcells, Stommel & Hubbard, 1999). Yeats (1997) described three characteristics that may influence body posture among schoolchildren 1) anthropometric dimensions, 2) doing certain activities and 3) anthropo-technical dimensions – school furniture design physical characteristics.

The ergonomic characteristics of school desks and chairs and their influence on the spine MSD among younger schoolchildren is an acute problem, which should motivate us to make an effort and use all the available resources to, at least, start solving this problem (Hedge & Lueder, 2008; Leeg, 2004; Linton, 1994).

The literature shows that the influence of rehabilitation exercises programs on lowering the risk of MSDs has often been overlooked by the researchers (Jones, Stratton, Reilly & Unnithan, 2004). The effects of alternative working positions (sitting-standing) are tested more and more, especially in the case of work places which require long periods of time in a seated position at a desk. However, this practice is still not widely used at schools (Heyman & Dekel, 2008).

Exercises focusing on the strengthening, mobility and control of the muscles of the spine have recently been used as a method of relieving spinal pain and lowering the risk of MSDs (MacDonald et al., 2006; Richardson et al., 2002). These exercises can improve nervous and muscular system functions, thus controlling the spine position. The aim of these exercises is to activate trunk muscles in order to relieve pain and strengthen the trunk muscle groups (Goldby, Moore, Doust & Trew, 2006; Kavčić, Grenier & McGill, 2004). Unstable platforms used when exercising, such as a Pilates ball, can be used to make exercising more difficult with or without body weight resistance (Anderson & Behm, 2005). Pilates balls exercises put all the body muscles into action so that more muscles are active compared to exercises done on fixed platforms. Therefore, using balls can improve the ability of dynamic balance, spine flexibility and stability as well as prevent MSDs (Marshall & Murphy, 2005). It has been stated in some studies (Marshall & Murphy, 2006) that ball exercises help relieve the pain and reduce MSDs as well as improve balance control through spine muscle strengthening. However, some previous studies have shown that there is no increase in muscular activities while exercising on unstable platforms (Drake, Fischer, Brown & Callaghan, 2006; Freeman, Karpowicz, Gray & McGill, 2006; Wahl & Behm, 2008).

For these very reasons the aim of this research was to study the influence of a ball exercise program on MSDs risk prevention among elementary schoolchildren. A very specific program was based on schoolchildren education about ergonomic risks and their prevention by specific exercises for each MSD noticed during sixteen-week.

METHODS

The sample of participants

The overall sample consisted of 55 students whose chronological age was 11, of both sexes, who were divided into two sub-samples: the experimental group (EG) numbering 28 students and the control group (CG) numbering 27 students. At the time of the measuring all the students were healthy and without significant musculo-skeletal disorders. All the students who participated had their parents' permission as well as permission from their school's ethic committee. The research was conducted in one elementary school in the city of Nis, Serbia.

The sample of measuring instruments

The Spinal Mouse (Quantum Health and Wellness Ltd, Wallasay, England) with the appropriate program support was used for the evaluation of the musculo-skeletal disorders of the spine in the sagittal and frontal plains (kyphosis, lordosis, thoracic scoliosis). This device is based on a non-invasive and echo work technology (Zsidai & Koscis, 2001).

Statistical methods

Descriptive statistical methods were applied for the basic statistical data analysis and the distribution of the initial and final measurement results for both groups. An analysis of variance for repeated measures was used for the analysis of the changes in results between the initial and final measuring (Repeated measures ANOVA), and the conclusion significance was set at the level of $p<0.05$. In order to determine the results of the difference in effects between the experimental and control group, a one-way analysis of variance was applied (One-way ANOVA) from the statistics package STATISTICA 7.0 for Windows (StatSoft, Inc., Tulsa, OK).

The experiment

The experimental group attended a lecture about ergonomic risks and the ways to reduce them. They were given posters and leaflets with the information about the appropriate way of carrying a schoolbag and a way of sitting (sitting posture). This group also implemented the ergonomic program package with 27 adapted rehabilitation exercises with a Pilates ball aimed at the noticed disorders. The exercises were always shown by the same instructor during regular physical education (PE) classes. The exercises were done twice a week for a period of sixteen weeks (one semester). The control group did not participate in any additional programs except their regular PE classes twice a week.

RESULTS

In order to assess the efficacy of the proposed exercise program, it was necessary to determine changes between the initial and final condition of the spine disorders for both the control and experimental groups, following the experimental period. Using an analysis of variance for repeated measures, a statistically significant difference between the arithmetic means of the initial and final measuring in both groups was calculated and the results are shown in Tables 1 – 4.

Table 1 Multivariate differences between the initial and final measuring of the postural status of the experimental group (EG)

Wilk’s Lambda	F	Effect df	Error df	Q
0.400	12.49	3	25	0.000*

Legend: Wilks' Lambda – Wilks’ test coefficient value for group centroid equity; F – coefficient F value for testing the significance of Wilks' Lambda; Effect df and Error df – degrees of freedom; Q – significance of the group centroid coefficient differences; * – statistically significant difference.

The analysis presented in tables 1 and 2 shows that, at the multivariate level, there is a statistically significant difference between the final and initial condition of the spine disorders among the experimental group at a significance level of Q= 0.000. Further analysis at the univariate level shows that statistically significant changes were noticed for kyphosis and thoracic scoliosis, but that there were no changes for lordosis. The changes are positive of course. Both kyphotic and scoliotic curves were significantly reduced following the four-month period of Pilates ball exercises.

Table 2 Univariate differences between the initial and final measuring of the postural status of the experimental group (EG)

Variable	Mean INI	Mean FIN	Mean Diff.	Mean Diff. (%)	F (1,27)	p
AKIF	36.18	31.21	-4.96	-13.71	19.43	0.000*
ALOR	-13.00	-12.04	0.96	-7.38	0.28	0.598
ASKT	6.11	3.25	-2.86	-46.81	23.61	0.000*

Legend: Mean INI – arithmetic mean of the initial condition; Mean FIN – arithmetic mean of the final condition; Mean Diff. – the arithmetic means difference between the initial and final condition; Mean Diff. (%) – the arithmetic means difference between the initial and final condition in percentages; F – the F-test value for testing the significance of differences between the arithmetic values; p – the significance of the difference between the arithmetic means coefficient; * – statistically significant difference

The analysis presented in tables 3 and 4 shows that there is no statistically significant difference between the initial and final condition of the spine disorders in the case of the control group at the multivariate level (Q= 0.325). A further analysis shows that that there is no statistically significant change for any measured spinal curves at the univariate level.

Table 3 Multivariate differences between the initial and final measuring of the postural status of the control group (CG)

Wilk's Lambda	F	Effect df	Error df	Q
0.868	1.22	3	24	0.325

Legend: Wilks' Lambda – Wilks' test coefficient value for group centroid equity; F – coefficient F value for testing the significance of Wilks' Lambda; Effect df and Error df – degrees of freedom; Q – significance of the group centroid coefficient differences; * – statistically significant difference.

Table 4 Univariate differences between the initial and final measuring of the postural status with the control group (CG)

Varijabla	Mean INI	Mean FIN	Mean Diff.	Mean Diff. (%)	F (1,26)	p
AKIF	38.07	39.63	1.56	4.10	2.00	0.169
ALOR	-14.59	-12.15	2.44	-16.72	1.83	0.188
ASKT	4.19	4.37	0.18	4.30	0.06	0.808

Legend: Mean INI – arithmetic mean of the initial condition; Mean FIN – arithmetic mean of the final condition; Mean Diff. – the arithmetic means difference between the initial and final condition; Mean Diff. (%) – the arithmetic means difference between the initial and final condition in percentages; F – the F-test value for testing the significance of differences between the arithmetic values; p – the significance of the difference between the arithmetic means coefficient; * – statistically significant difference

After it was noticed that unlike the school PE program, the experimental Pilates ball exercise program caused significant positive changes in spinal curves, it was necessary to analyze the differences between the changes in both groups. A multi/univariate analysis was used for that purpose and the difference values of the arithmetic means between the initial and final condition of each participant represented the raw data for analysis both in the case of the experimental and control group.

A statistically significant difference between the effects of the two programs was noticed at the multivariate level at the level of significance Q= 0.000 (Table 5). The analysis presented in table 6 shows that the difference between the effects of the two exercise programs performed by the experimental and control group was caused by the difference which occurred in the kyphotic and thoracic scoliotic curves. A further analysis showed those differences to be statistically significant at the p= 0.000 and p= 0.002 level. Moreover, the experimental program affected the spine disorders, reducing it more than the school program did, which is shown by the arithmetic means of the difference between the initial and final conditions (Mean Diff.) in both the experimental and control group.

Table 5 Multivariate differences of the two programs effects on postural status

Wilk's Lambda	F	Effect df	Error df	Q
0.674	8.24	3	51	0.000*

Legend: Wilks' Lambda – Wilks' test coefficient value for group centroid equity; F – coefficient F value for testing the significance of Wilks' Lambda; Effect df and Error df – degrees of freedom; Q – significance coefficient of the group centroid differences; * – statistically significant difference.

Table 6 Univariate differences of the two programs effects on postural status

Variable	Mean Diff. EG (N=28)	Mean Diff. CG (N=27)	F (1,50)	p
AKIF	-4.96	1.56	17.13	0.000*
ALOR	0.96	2.44	0.34	0.565
ASKT	-2.86	0.18	10.22	0.002*

Legend: Mean Diff. EG – the arithmetic means difference between the initial and final conditions with the experimental group; Mean Diff. CG – the arithmetic means difference between the initial and final conditions with the control group; N – the number of participants; F – the F- test value for testing the significance of the differences between the arithmetic values; p - significance coefficient of the difference between the arithmetic means; * – statistically significant difference.

The results following the experimental program have shown significantly lowered values for the kyphotic and thoracic scoliotic curve in the case of the experimental group (EG), whereas the condition deteriorated in the control group (CG), but with no statistical significance. As for lordosis, there have not been any significant changes in either group during the experimental treatment.

DISCUSSION

Based on the research results of the statistical analysis, in the discussion we can conclude that the Pilates ball exercise program for reducing the spine MSDs in the case of the experimental group during a sixteen-week period caused a statistically significant reduction of the spinal curve in the thoracic part, whereas the same situation was not noticed in the lumbar region. At the same time the school PE program did not have any effects on reducing the spinal curves in the thoracic part. However, there was a thoracic curve incidence rise in the sagittal and frontal part. These changes are not statistically significant, and are noted only on the numerical level.

Considering the small sample of participants (EG=28; CG=27), the concluding level of the statistical significance gives the full picture regarding the spine MSDs new changes among both groups of participants, but on the numerical level these changes are more obvious. Taking into consideration the significance of the effects of the applied programs on the spine MSDs reduction, it is important to emphasize that each (even the smallest) MSDs reduction is extremely important for children's life quality improvement, especially in the stages of musculoskeletal development. The constant application of proposed program could contribute to improving final postural status among children and preventing the development of MSDs.

For these reasons it is important to evaluate the experimental programs in terms of numbers, especially the ones represented in percentages where we can see their practical contribution to the spine MSDs reduction. The changes caused by the application of the experimental program, presented in percentages, are significant in the case of the spinal curves in the thoracic area, in the sagittal area, as well as in frontal part. As for kyphosis, there was a curve reduction for 4.96^0 or 13.71%, which represents a high percentage of improvement and is in accordance with findings from other research studies (Weiss & Turnbull, 2010; Weiss & Werkmann, 2009; Djurasović & Glassman, 2007; Lowe & Line, 2007; Glassman, Bridwell, Dimar, Horton & Berven, 2005; Pizzutillo, 2004; Weiss Dieckmann & Gerner, 2003; Wenger, 1999). There was a thoracic scoliosis curve reduction (2.86^0 or 46.81%), which represents a significant improvement in the damaged postural status reduction among eleven-year-old children. These results are in accordance with other researchers' results (Negrini, Zaina, Romano, Negrini & Parzini, 2008; Otman, Kose & Yakut, 2005; Mooney & Brigham, 2003; Mamyama, Kitagawal, Takeshita & Nakainura, 2002; El-Sayyad & Conine, 1994; Weiss, 1992). Given the significant influence Pilates ball exercises have on the activation and strengthening of trunk muscles compared to the exercises on stable platform, some authors who researched into the effects of Pilates ball exercise on muscles strengthening aimed at postural disorder reduction argue that it is highly important to apply the findings (results) (Park & Yoo, 2011; Escamilla et al., 2010; Marshall & Desai, 2010; Petrofsky et al., 2007). On the other hand, some authors state that exercises on unstable platforms (such as Pilates balls) do not have any significant effects on muscles activation and MSDs reduction as compared to exercises on stable platforms (Wahl et al., 2008; Nuzzo, McCaulley, Cormie, Cavill & McBride, 2008). Exercising on unstable platforms provides the spine stability due to the co-activating of global and local muscles at the beginning of the motor control (Carter, Beam, McMahan, Barr & Brown, 2006). Exercising on unstable surfaces using Pilates balls mainly activates local muscles for stabilization (Cooke, 1980). The overall result is muscles activation growth and motor control improvement, which ultimately leads to growth in muscle strength (Cug, Ak, Ozdemir, Korkusuz & Behm, 2012). It is important to examine if Pilates ball exercises can influence some muscles actions and activities more than other types of exercises.

CONCLUSION

The specially defined program (specific Pilates ball exercises) leads to reduction of the MSDs incidence risk among fourth-graders. The analysis shows that the experimental actions applied had positive effect on the changes in kyphotic and thoracic scoliotic bad posture among the experimental group participants. However, there was no significant influence on the lordotic posture.

This study results have shown that Pilates ball exercises cause muscular activity in all the treated muscles, so strength exercises in accordance with their intensity are recommended for the students of this age. Exercises which cause stomach activity must be repeated more in order to adapt stamina training. Although this study has shown that Pilates ball exercises can provide significant activation of the muscles of the whole body, the practical difficulties of doing exercises (lack of any or not enough Pilates balls at schools), along with the risks of unstable surfaces, can outweigh their potential benefits. On the other hand, the observed positive effects of the program in the prevention of MSDs should be considered as an important step in the development of future healthy, working age population.

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EFEKTI ERGONOMSKOG PROGRAMA VEŽBI SA PILATES LOPTOM NA SMANJENJE RIZIKA OD NASTANKA MIŠIĆNO-SKELETNIH POREMEĆAJA

Uvod: Mali broj istraživača je proučavao uticaj rehabilitacionih vežbi na smanjenje rizika od nastanka mišićno-skeletnih poremećaja (MSP). Iz tih razloga je potrebno proučavanje uticaja programa vežbi na prevenciju i smanjenje rizika od razvoja MSP kod dece školskog uzrasta. Poseban program baziran je na edukaciji školske dece o ergonomskim rizicima i njihovoj prevenciji, pomoću specifičnih vežbi sa pilates loptom za svaki uočeni MSP, sa pretpostavkom da će njegova primena u trajanju od 16 nedelja značajno uticati na smanjenje rizika od nastanka MSP. Metode: Ukupan uzorak ispitanika je činilo 55 učenika hronološke starosti 11 godina oba pola, koji je podeljen u dva subuzorka: eksperimentalna grupa (EG) sa 28 i kontrolna grupa (KG) sa 27 učenika. Za procenu mišićno-skeletnih poremećaja kičmenog stuba u sagitalnoj i frontalnoj ravni (kifoza, lordoza i torakalna skolioza) korišćen je Spinal Mouse sa odgovarajućom programskom podrškom. Navedeni uređaj poseduje neinvazivnu, ultrazvučnu tehnologiju rada. Rezultati sa diskusijom: Rezultati provedenog eksperimentalnog programa ukazuju na značajno smanjenje vrednosti kifotične i torakalne skoliotične krivine kod eksperimentalne grupe (EG), dok se stanje istih kod kontrolne grupe (KG) pogoršalo, ali ne i statistički značajno. Kod lordoze nije bilo značajnih promena ni kod jedne grupe u periodu eksperimentalnog tretmana. Analizom varijanse je utvrđeno da je program vežbi sa pilates loptom u odnosu na školski program vežbi dao statistički značajne efekte na smanjenje MSP kod kifotične i torakalne skoliotične krivine, a da kod lordoze nije bilo značajnijih efekata nakon eksperimentalnog tretmana. Zaključak: Analizom efekata posebno definisanog ergonomskog programa, u formi specifičnih vežbi sa pilates loptom, na smanjenje rizika od nastanka MSP kod učenika četvrtog razreda osnovne škole, može se zaključiti da su primenjeni eksperimentalni postupci pozitivno uticali na smanjenje MSP kičmenog stuba kod ispitanika eksperimentalne grupe, dok kod kontrolne grupe nije bilo značajnih promena.

Ključne reči: *Mišićno-skeletalni poremećaji, ergonomija, učenici, pilates lopta, efekti programa vežbi.*