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Original Article

Effects of an exercise program on the dynamic function of the spine in female students in secondary school

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Abstract:

The study presents and points to the importance of implementing intervention exercise programmes in physical and sport education classes. It aims to explain diversification and realization of innovative syllabi through health-oriented exercise programmes with the focus on the primary level of preventive healthcare among the female secondary-school students and improvement of dynamic function of the spine that reflects proper function of the muscle system. The experimental groups comprised 25 second-year female students at one secondary school in the town of Liptovský Mikuláš (A group n=13: age 16.4±0.6 years, height=168.1±3.9 cm, weight=58.3±2.6 kg, B group n=12: age 16.9±0.9 years, height=167.1±4.5 cm, weight=56.6±3.1 kg). Their selection was intentional. The data were obtained by means of standardized methods used in pedagogical and clinical practice for assessment of dynamic function of the spine. The quantitative data obtained from individual groups were processed by means of the nonparametric test for dependent monitoring (one-sample Wilcoxon signed-rank, $p<0.01$) and the Kruskal-Wallis test ($p<0.01$). The results in both experimental groups A and B significantly ($p<0.01$) proved a positive effect of the 12-week health-oriented exercise programme on overall dynamic function of the spine in the sagittal and lateral planes. The results also confirmed a beneficial influence of the exercise programme on the monitored determinants without significant differences between the experimental groups ($p>0.05$).
Key words: dynamic function of the spine, exercise programme, physical and sport education, female students.

Introduction

Even though physical activity is closely related to quality of life, lifestyle and health, the sedentary lifestyle has become a major social problem not only in the USA, but also in Europe and Slovakia and it affects school children and adolescents as well (Boreham & Riddoch, 2001; Nemček, 2009, Ihász & Rikk, 2010; Štemberger, Knjaz & Tománek, 2011; Fyodorov & Erlikh, 2016; Żukowska, Krygowski, Szark-Eckardt & Zając, 2016). Health-oriented physical education is one of the most significant issues of the modern society at the beginning of the millennium. Human health is also connected with the musculoskeletal system, the functional disorders of which have become negative syndromes or lifestyle diseases of the modern age. Several studies point to negative development of the musculoskeletal system in school-aged children and adolescents with the focus on bad posture, muscle imbalance and improper function of the spine or feet (Chen, Wang, Tsuang, Liao, Huang & Hang, 1998; Bird & Payne, 1999; Kopecký, 2004; Kopecký & Ely, 2007; Defranco, Carl, Goodwin, Bergfeld & Bergfeld, 2009; Łubkowska, 2017). These health problems are often the reason why pupils and students are fully excused from attending physical and sport education classes. The prevalence of functional disorders of the musculoskeletal system in school-aged children and adolescents has been confirmed also by other authors and their studies: (Acasandrei & Macovei, 2014; Mitova, Popova & Gramatikova, 2014; Mitova, 2015; Azabagic, Spahic, Pranjic & Mulic, 2016). The most common symptom of functional changes in the musculoskeletal system is pain (Balague, Troussier & Salminen, 1999; Bird & Payne, 1999; Feldman et al., 2001; Watson, Papageorgiou, Jones, Taylor, Symmons, Silman & Macfarlane, 2002; Hirayama et al., 2006; Syazwan et al., 2011; Arya, 2014). The pain is connected with changes in tissue tension. Everything that increases muscle tension increases pain, and vice versa. What is more, reflex actions lead to painful muscle spasms that later accompany vertebrogenic diseases (spasm-pain-spasm) (Jakubínová, 2007; Nemček & Lojek, 2009).

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The posture, which is the reflection of the spine shape and function, is one of the symptoms of functional disorders in the musculoskeletal system (Granata & Wilson, 2001). Lemos, Santos & Gaya (2012) claim that a longer period of time spent in a sitting position affects muscle length at the back of the thigh (m. biceps femoris, m. semitendinosus, m. semimembranosus) and leads to muscle shortening. The muscles in the posterior compartment of the thigh are attached to the ischial tuberosity (tuber ischiadicum) and, thus, significantly affect the position of the pelvis in the sagittal plane. As a result, changes in the length of the muscles at the back of the thigh may influence the position of the pelvis and the whole spine as well (Carregaro, Silva & Coury, 2007). Disruption of balance in the musculoskeletal system caused by hypokinesis and unilateral static overload results in functional and, later, also in tissue changes in the stabilizing deep autochthonous muscles of the spine, so-called dynamic ligaments (Véle, 2006).

Therefore, it is important to point out that while in the past health was determined mainly by biological factors, in these says it is being increasingly influenced by social factors. Health cannot be obtained as a genetically determined and unchangeable condition. The genetic basis is only a biological potential that can develop in a positive or a negative way. One of the primary tasks of all human beings is to take care of their health. In contrast to the past, increased emphasis is being placed on personal responsibility for our own health (Bendíková, 2016a). These changes are reflected also in the curricular transformation in the Slovak school system that took place in 2008. It modified the name of the educational process. The physical and sport education syllabi were included in the field called Health and Movement. Prior to this transformation, physical and sport education had been focused mainly on performance. Since then more emphasis has been placed on development of students' competences, values and attitudes. The aim of this school subject is more connected with health and leading of a healthy lifestyle. What is more, the physical and sport education syllabus is now more open and diverse. It comprises four modules (1. Health and its Disorders; 2. Healthy Lifestyle; 3. Physical Efficiency and Performance; 4. Sports Activities within the Movement Routine). Furthermore, the school reform determined the minimum number of physical and sport education classes to two classes per week (Hardman, 2008; Müller et al., 2008; Rozim & Marko, 2015; Nagy & Müller, 2016), which is insufficient for several reasons.

Nowadays the school educational programme allows changes in the physical and sport education syllabus. The number of classes may extend to three or more classes per week, which may also help to prevent the prevalence of functional disorders of the musculoskeletal system among the school-aged children and adolescents. Bendíková (2016a) points out that the close connection between theory and practice is very important also when it comes to the musculoskeletal system: "Physical and sport education directly or indirectly creates the space for diversification and innovation of the curricula and classes that should have a positive effect on health determinants as well as physical, functional and motor development and health-focused physical efficiency of school-aged children and adolescents".

Positive effects of exercise programmes on the musculoskeletal system have been described in several studies. Whilst there are discrepancies regarding the length of intervention (Rowe & Jacobs, 2012), the authors of these studies all agree on a positive impact of exercise programmes. These programmes mostly last from 10 to 12 weeks during which exercise is performed 3 times per week. Positive changes are noticeable already after 6 weeks of intervention, when exercise is done 2 to 3 times per week and lasts 30 minutes (Emery, De Serres, McMillan & Côté, 2010; Lee, Park & Kim, 2013; Tomková & Palaščáková-Špringrová, 2013; Vetkasov, Hošková & Pokuta, 2014; Dewar, Love & Johnston, 2015; Kim, Cho, Park & Yang, 2015; Bendíková, 2016b; Mrozkowiak, Szark-Eckard, Żukowska & Augustyńska, 2016; Łubkowska, Zdeb & Mroczek, 2015).

Insufficient primary prevention and diagnostics or ignorance of functional changes in the musculoskeletal system often result in the prevalence of vertebrogenic disorders in adulthood, when their treatment is limited or even impossible. What is more, they also lead to increasing occurrence of other structural multifactorial disorders (Fejer & Ruhe, 2012). The research aimed to obtain and expand the knowledge about the effect of exercise programmes performed during physical and sport education classes on dynamic function of the spine in the sagittal and lateral planes in secondary-school female students.

Methods

Subject characteristics

The experimental groups comprised 25 second-year female students at one secondary school in the town of Liptovský Mikuláš (A group n=13: age 16.4±0.6 years, height=168.1±3.9 cm, weight=58.3±2.6 kg, B group n=12: age 16.9±0.9 years, height=167.1±4.5 cm, weight=56.6±3.1 kg). Selection of the participants was intentional. They did not use to be interested in physical and sport education classes and were diagnosed with functional disorders of the musculoskeletal system during the general medical examination. The girls were divided into two experimental groups A and B according to their classes, timetables and teachers. The Table 1 shows their primary characteristics.

Table 1 Characteristics of experimental groups A, B (n = 25)

Group/factors	n	Age in decimal years	Body height (cm)	Body weight (kg)	BMI
EG A group	13	16.4±0.6	168.1±3.9	58.3±2.6	21.4±0.3
EG B group	12	16.9±0.9	167.1±4.5	56.6±3.1	21.3±0.2

EG-experimental group, n-number, BMI-Body mass index

Measurement organisation

Dynamic function of the spine was assessed during the general medical examination by means of a standardized method used in medicine and physical and sport education fields (Vojtaššák, 2000). The initial (January 2017), continuous (March 2017) and final (May 2017) assessments conducted by a doctor aimed to determine efficiency of the exercise programmes and were based on the functional status of the students' muscle system. The exercise programmes were conducted three times per week and lasted 25 minutes (Monday/10.00-10.45, Wednesday/8.50-9.35 and Friday/10.00-10.45). They were led by physical and sport education teachers who have been teaching physical and sport education for more than 15 years. The exercise programmes comprised a total of 36 school classes that were taught concurrently.

Measurement taking

Assessment of dynamic function of the spine

I. Thomayer's test (Th) - (forward bend aimed at touching the floor, overall mobility of the spine)

Procedure: the patient is in a standing position and deeply bends forward towards the floor.

Standard: patients touch the floor with their fingertips.

Decreased mobility: doctors can measure the distance between the fingertips and the floor.

II. Schober's test (Sch) - (lumbar spine)

Procedure: a mark is placed at the level of the fifth lumbar vertebra and the second mark is placed 10 cm above the first mark.

Standard: when the patient bends forward as far as possible, the increase in the distance between the two points should be from 4 to 6 cm.

Decreased mobility: the distance is shorter than the standard one.

III. Stibor's test (St) – (lumbar and thoracic spine)

Procedure: the examiner measures the distance between the spinous process of the 7^{th} cervical vertebra and the fifth lumbar vertebra (C7–L5) in a standing position.

Standard: the increase in this distance when the patient bends forward is from 7.5 to 10 cm.

Decreased mobility: when the distance is shorter than the standard one.

IV. Otto's inclination and reclination test (Ott) – (thoracic spine)

Procedure: The patient is in a standing positon. A mark is placed on his/her back at the level of the 1^{st} thoracic vertebra and the second mark is placed 30 cm below the first one.

Standard: when the patient bends forward, this distance increases by 2 to 3 cm. When the patient bends backward, the distance decreases by 2.5 to 3 cm. The total of the deviations should be 6 cm.

Decreased mobility: when the total of the deviations is lower than the standard. The total of inclination presents an index of the sagittal range of motion of the thoracic spine.

V. Lateral flexion test (bending sideways, left and right) – (lateral mobility of the lumbar spine).

Procedure: the examiner measures how far the middle finger can move along the thigh while the patient bends sideways as far as possible.

Physiological standard is from 20 to 22 cm.

Decreased mobility: when the distance is shorter than the standard one.

Increased mobility: when the distance is longer than the standard one.

Data Analyses

The results of our study focused on dynamic function of the spine were processed by means of the following primary mathematical and statistical methods: arithmetic mean (x) that we used to obtain average values of the results we achieved from assessment of individual determinants in both experimental groups (A, B); extent of variation ($R_{max-min}$) that we needed to express the difference between the average minimum and maximum value; standard deviation (SD) that quantifies the amount of variation of values and median (M) that expresses values obtained by comparing individual groups in terms of efficiency of the exercise programmes. Furthermore, the statistical significance of the difference in monitored determinants (of dynamic function of the spine) between initial-and-continuous and initial-and-final assessments and measurements was determined by means of the nonparametric test for dependent monitoring called the Wilcoxon signed-rank test (one-sample W_{test}). Efficiency of individual exercise programmes in both groups was determined and compared by means of the Kruskal-Wallis non-parametric test (KW_{test}). The significance of differences between individual experimental groups was determined at the standard level of significance ($p<0.01$) and ($p<0.05$). We also used induction, deduction, synthesis and analysis as well as effect size to assess the practical and statistical significance. The results are presented in tables so that the values measured in individual groups can be compared.

Results and discussions

Following the aim of the study, we present the part of the results that require further and more exact monitoring and processing. The presented results cannot be generalized. They need to be perceived as orientation and basic information useful for development of health-oriented physical and sport education syllabi.

The initial assessment of the forward bend of the trunk, which we did by means of the Thomayer's test, showed the limited motion of the spine in the sagittal plane in both groups (A, B).

None of the girls in the experimental groups were able to bend forward within normal values (they were not able to touch the ground with their fingertips). In group A, the distances ranged from max. -35 cm to min. -6 cm and in group B the measured values ranged from max. -30 cm to min. -5 cm. What is more, the initial measurements showed that there was a higher extent of variation $R_{max-min}$ (-29 cm) in group A in comparison to group B ($R_{max-min}$ -25 cm). This difference was confirmed also by the initial average values in both groups (A-16.5±7.98 cm, B-16.1±7.8 cm).

After the girls completed the exercise programmes, we performed the final measurements during which the girls in both experimental groups met the standard according to Vojtaššák (2000). The measured values (A-1.8±2.76 cm, B-0.8±1.21 cm) also proved improvement of joint mobility of the spine. Testing of the significance of differences between the initial and final assessments (A14.56±5.51, B15.3±6.52) showed that both groups improved significantly (AW_{test}=2.934, r=0.69, p<0.01; BW_{test}=3.059, r=0.68, p<0.01) as far as the Thomayer's test results are concerned. However, there were no significant differences between the groups A and B (KW_{test}=0.0478, p>0.05). Table 2 shows that most of the girls in both groups met the standard according to the Thomayer's test, which we regard as a positive finding.

Table 2 Thomayer's test results in experimental groups A, B (n = 25)

Group	A (n = 13)					B (n = 12)				
Factors	V1	V2	R1	V3	R2	V1	V2	R1	V3	R2
x	-16.5	3.2	13.3	-1.8	-14.6	-16.1	2.3	13.8	-0.8	-15.3
min	-35.0	1.0	5.0	-9.0	-26.0	-30.0	0.0	5.0	-3.0	-28.0
max	-6.0	10.0	25.0	0.0	-6.0	-5.0	4.0	27.0	0.0	-5.0
$R_{max-min}$	-29.0	9.0	20.0	9.0	20.0	-25.0	4.0	22.0	3.0	23.0
SD	7.98	2.59	5.83	2.76	5.51	7.08	1.03	6.43	1.21	6.52
M	-15.00	2.00	13.00	0.00	-15.00	-16.00	2.50	13.00	0.00	-14.50
Wilcoxon	2.934, p<0.01			2.934, p<0.01		3.059, p<0.01			3.059, p<0.01	
KW_{test}						0.0478, p>0.05				

V1–initial measurement, V2-continuous measurement, V3-final measurement, R1-difference between V1-V2, R2-difference between V1-V3

We also found significant statistical improvement (AW_{test}=2.934, BW_{test}=3.059, p<0.01) between the initial (A16.5±7.98 cm, B16.1±7.8 cm) and continuous (A3.2±2.59 cm; B2.3±1.03 cm) measurements with the difference between the average values (A13.3±5.58 cm, B13.8±6.43 cm) in both experimental groups. The extent decreased and got closer to the standard with smaller deviations. Furthermore, the exercise programmes increased the values (still within the standard) measured during the Schober's and Stibor's tests in both groups (A, B).

Table 3 Schober's test in experimental groups A, B (n = 25)

Group	A (n = 13)					B (n = 12)				
Factors	V1	V2	R1	V3	R2	V1	V2	R1	V3	R2
x	2.7	5.1	2,4	5.6	2.9	3.2	4.9	1.7	5.7	2.5
min	1.9	4.0	2,0	4.5	3.6	2.0	4.5	1.2	4.9	3.5
max	3.5	6.0	3,5	6.0	2.0	3.9	5.1	3.0	6.0	1.7
$R_{max-min}$	1.6	2.0	1.5	1.5	1.6	1.9	0.6	1.8	1.1	1.8
SD	0.47	0.47	0.49	0.51	0.43	0.53	0.22	0.48	0.45	0.52
M	3.00	5.00	2.10	5.80	3.00	3.10	5.00	1.60	5.95	2.50
Wilcoxon	2.934, p<0.01			2.934, p<0.01		3.059, p<0.01			3.059, p<0.01	
KW_{test}						0.0466, p>0.05				

V1–initial measurement, V2-continuous measurement, V3-final measurement, R1-difference between V1-V2, R2-difference between V1-V3

Testing of mobility of the lumbar spine by means of the *Schober's test* showed that in both experimental groups (A, B) the initial average values (A2.7±0.47 cm, B3.2±0.53 cm) were smaller than the standard values (4-6 cm) according to Vojtaššák (2000). The initial measurements showed the biggest extent of variation $R_{max-min}$ 2 cm in group A and the smallest extent of variation $R_{max-min}$ 1 cm in group B.

We also found significant statistical improvement (AW_{test}=2.934, r=0.66, p<0.01; BW_{test}=3.059, r=0.65, p<0.01) between the initial (A2.7±0.47 cm, B3.2±0.53 cm) and continuous measurements (A5.1±0.47 cm, B4.9±0.22 cm) with the difference between the average values in group A 2.4±0.49 cm and in group B 1.7±0.48 cm. The final values of the Schober's test, which was conducted after completion of the exercise programmes, (A5.6±0.51 cm, B5.7±0.45 cm) ranged from 4 to 6 cm, which Vojtaššák (2000) consider as standard. There was a significant improvement (AW_{test} = 2,934; BW_{test} = 3.059, p<0.01) confirmed by the difference between the average values in group A 2.9±0.43 cm and in group B 2.5±0.52 cm (Table 3). As far as the significance of the increase in values is concerned, we can say that both experimental groups (A, B) significantly improved their results of the Schober's test. There were no significant differences between the results in individual groups (KW_{test}=0.0466, p>0.05).

We conducted the Stibor's test in order to measure mobility of the lumbar and thoracic spine. The values measured during the initial assessment were lower than the standard values (from 7.5 cm to 10 cm) (Vojtaššák, 2000). The average values in group A were 7.1±0.47 cm and in group B 6.9±0.35 cm. However, these values increased after the continuous measurement (A8.1±0.68 cm, B8.6±0.45 cm) and were even higher after the final measurement: A8.9±0.77 cm, B9.3±0.56 cm. Comparison of the initial and final measurements between individual experimental groups (AW_{test}=2.934, r=0.69, BW_{test}=3.059, r=0.68) and also between the initial and continuous measurements (AW_{test}=2.803, BW_{test}=3.059) showed the significant improvement ($p<0.01$) in the monitored region of the spine, which was achieved due to the exercise programmes done during physical and sport education classes (Table 4).

Table 4 Stibor's test in experimental groups A, B (n = 25)

Group	A (n = 13)					B (n = 12)				
Factors	V1	V2	R1	V3	R2	V1	V2	R1	V3	R2
x	7.1	8.1	1.1	8.9	1.8	6.9	8.6	1.7	9.3	2.4
min	6.0	7.0	0.0	7.3	3.0	5.9	8.0	0.9	8.3	3.9
max	8.0	9.0	2.0	10.0	1.0	7.5	9.2	3.1	10.0	1.2
$R_{max - min}$	2.0	2.0	2.0	2.7	2.0	1.6	1.2	2.2	1.7	2.7
SD	0.47	0.68	0.53	0.77	0.51	0.35	0.45	0.60	0.56	0.67
M	7.00	8.00	1.00	8.90	1.90	7.00	8.70	1.55	9.30	2.30
Wilcoxon	2.803, p<0.01		2.934, p<0.01			3.059, p<0.01		3.059, p<0.01		
KW_{test}	0.0533, p>0.05									

V1–initial measurement, V2-continuous measurement, V3-final measurement, R1-difference between V1-V2, R2-difference between V1-V3

Regarding the significance of the increase in values, we can say that both experimental groups (A, B) significantly improved their results of the Stibor's test. There were no significant differences between the results in individual groups (KW_{test}=0.0533, $p>0.05$).

The initial results of the Otto's inclination and reclination test showed decreased mobility of the thoracic spine in individual members of both experimental groups as none of them met the standard value (6.0 cm). The initial values in group A ranged from min. 4.0 cm to max. 5.2 cm with the extent of variation $R_{max – min}$ 1.2 cm. We measured the biggest difference $R_{max – min}$ 3.5 cm in group B, where the values ranged from min. 2.0 cm to max. 5.5 cm. The continuous measurements proved the positive effect of the exercise programmes, which can be proved by the $R_{max – min}$ values in both groups. The values in group A ranged from min. 5.0 cm to max. 6.0 cm with the extent of variation $R_{max – min}$ 1 cm. The values in group B were the same (min. 5.0 cm to max. 6.0 cm, extent of variation $R_{max – min}$ 1 cm).

The minimum and maximum values of the final measurement in both groups were standard 6.0 cm (ideal condition). Comparison of the initial (A4.6±0.48 cm, B4.4±0.96 cm) and final measurements (A6.0 cm, B6.0 cm) and the differences between the average values (A1.4±0.48 cm, B1.6±0.96 cm) shows that, during the initial assessment, all the girls had problems with reclination, especially in the lumbar region of the spine. The difference between the initial and final measurements and the significant improvement in the monitored region of the spine (AW_{test}=2.934, r=0.69; $p<0.01$; BW_{test}=3.059, r=0.68, $p<0.01$) prove the positive effect of the exercise programmes (Table 5).

We found significant statistical improvement (AW_{test}=2.934, BW_{test}=3.059, $p<0.01$) of differences between average values in groups A1.2±0.42 cm and B1.5±0.85 cm also between the initial (A4.6±0.48 cm, B4.4±0.96 cm) and continuous (A5.8±0.32 cm, B5.9±0.19 cm) measurements.

As far as the significance of the increase in values is concerned, we can say that both experimental groups (A, B) significantly improved their results of the Otto's inclination and reclinaton test. There were no significant differences between the results in individual groups (KW_{test}=0.0463, $p>0.05$).

Table 5 Otto's test in experimental groups A, B (n = 25)

Group	A (n = 13)					B (n = 12)				
Factors	V1	V2	R1	V3	R2	V1	V2	R1	V3	R2
x	4.6	5.8	1.2	6.0	1.4	4.4	5.9	1.5	6.0	1.6
min	4.0	5.0	2.0	6.0	2.0	2.0	5.5	3.5	6.0	4.0
max	5.2	6.0	0.8	6.0	0.8	5.5	6.0	0.5	6.0	0.5
$R_{max - min}$	1.2	1.0	1.2	0.0	1.2	3.5	0.5	3.0	0.0	3.5
SD	0.48	0.32	0.42	0.00	0.48	0.96	0.19	0.85	0.0	0.96
M	4.50	6.00	1.00	6.00	1.50	4.75	6.00	1.25	6.0	1.25
Wilcoxon	2.934, p<0.01		2.934, p<0.01			3.059, p<0.01		3.059, p<0.01		
KW_{test}	0.0463, p>0.05									

V1–initial measurement, V2-continuous measurement, V3-final measurement, R1-difference between V1-V2, R2-difference between V1-V3

Lateral flexion test. The initial measurements of lateral flexion showed that all the girls in both experimental groups had better results of the right lateral flexion in comparison to the left lateral flexion.

However, these differences were not significant. None of the girls from both experimental groups (A, B) met the standard (20–22 cm).

The results of the right lateral flexion initial measurements (A17.8±0.83 cm, B16.9±0.95 cm) proved decreased mobility of the lumbar spine in contrast to the results of the final measurements (A21.8±0.39 cm, B21.8±0.37 cm), which were standard (Vojtaššák, 2000) in both experimental groups with the difference between the average values (A3.9±0.67 cm, B4.9±0.86 cm) and which were statistically significant (AW_{test}=2.934, r=0.69, p<0.01, BW_{test} = 3.059, r=0.63, p<0.01) (Table 6).

Table 6 Right lateral flexion testing in experimental groups A, B (n = 25)

Group	A (n=13)					B (n=12)				
Factors	V1	V2	R1	V3	R2	V1	V2	R1	V3	R2
x	17.8	21.5	3.6	21.8	4.0	16.9	21.2	4.3	21.8	4.9
min	16.0	21.0	5.0	21.0	5.0	15.0	21.0	6.0	21.0	6.0
max	19.0	22.0	3.0	22,0	3.0	18.0	22.0	3.0	22.0	4.0
$R_{max - min}$	3.0	1.0	2.0	1.0	2.0	3.0	1.0	3.0	1.0	2.0
SD	0.83	0.50	0.77	0.39	0.60	0.95	0.37	0.83	0.37	0.86
M	18.00	21.00	3.00	22.00	4.00	17.00	21.00	4.00	22.00	5.00
Wilcoxon	2.934, p<0.01			2.934, p<0.01		3.059, p<0.01			3.059, p<0.01	
KW_{test}	0.0503, p>0.05									

V1–initial measurement, V2-continuous measurement, V3-final measurement, R1-difference between V1-V2, R2-difference between V1-V3

We also found significant statistical improvement (AW_{test}=2.934, BW_{test} = 3.059, p<0.01) between the initial (A17.8±0.83 m, B16.9±0.95 cm) and continuous (A21.5±0.50 cm, B21.2±0.37 cm) measurements with the difference between the average values in group A 3.6±0.77 cm and in group B 4.3±0.83 cm. As far as the significance of the increase in values is concerned, we can say that both experimental groups (A, B) significantly improved their results of the right lateral flexion test. There were no significant differences between the results in individual groups (KW_{test}=0.0503, p>0.05).

The results of the left lateral flexion testing showed only small differences between the right and left lateral flexion, which might be connected with lack of activity or similar involvement of the right and left sides of the body. Similarly to right lateral flexion, the results of the initial left lateral flexion measurements in both groups (A16.9±1.24 cm, B16.9±1.11 cm) proved decreased mobility of the lumbar region of the spine in comparison to the final measurements (A21.6±0.48 cm, B21.7±0.47 cm) with the statistically significant difference **(**AW_{test}=2.934, r=0.66, p<0.01; BW_{test}=3.059, r=0.62, p<0.01) and the difference between the average values (A4.7±1.05 cm, B4.8±1.09 cm) in both experimental groups (Table 7).

Table 7 Left lateral flexion testing in experimental groups A, B (n = 25)

Group	A (n=13)					B (n=12)				
Factors	V1	V2	R1	V3	R2	V1	V2	R1	V3	R2
x	16.9	21.5	4.5	21.6	4.7	16.9	21.5	4.6	21.7	4.8
min	14.0	21.0	7.0	21.0	7.0	15.0	21.0	7.0	21.0	7.0
max	18.0	22.0	4.0	22.0	4.0	18.0	22.0	3.0	22.0	3.0
$R_{max - min}$	4.0	1.0	3.0	1.0	3.0	3.0	1.0	4.0	1.0	4.0
SD	1.24	0.50	0.89	0.48	1.05	1.11	0.50	1.11	0.47	1.09
M	17.00	21.00	4.00	22.00	4.00	17.00	21.50	4.00	22.00	4.50
Wilcoxon	2.934, p<0.01			2.934, p<0.01		3.059, p<0.01			3.059, p<0.01	
KW_{test}	0.0506, p>0.05									

V1–initial measurement, V2-continuous measurement, V3-final measurement, R1-difference between V1-V2, R2-difference between V1-V3

The final results were standard according to Vojtaššák (2000). There were no significant statistical differences between the results in groups A and B (KW_{test}=0.0503, p>0.05).

We also found significant statistical improvement **(**AW_{test}=2.934, BW_{test}=3.059, p<0.01) between the initial (A16.9±1.24 cm, B16.9±1.11 cm) and continuous (A21.5±0.50 cm, B21.5±0.50 cm) measurements with the difference between the average values 4.5±0.89 cm in group A and 4.6±1.11 cm in group B.

As regards the significance of the increase in values, we can say that both experimental groups (A, B) significantly improved their results of the left lateral flexion test. There were no significant differences between the results in individual groups (KW_{test}=0.0506, p>0.05).

Joint mobility is an important prerequisite for performance of movements. It helps the body to perform and learn movements faster. It also improves efficiency of muscle activity, decreases muscle fatigue and has the potential to prevent a lot of injuries. Mobility is generally considered as the ability of the body to perform movements of the whole body and its individual parts to a large extent (amplitude). Mobility is mainly affected by the anatomy of individual joints as well as flexibility and strength of tissues, tendons and muscles, including the central nervous system (Lewit, 1998). People have basic (natural) flexibility that first increases and then slowly decreases over the course of their lives (Véle, 2006). These changes also influence the musculoskeletal system in terms of posture and the muscle system.

When assessing dynamic function of the spine, it is necessary to consider initial results of the spinal mobility tests (Schober's, Stibor's and Thomayer's tests) that are directly connected with shortening of the spinal erectors in the lumbar region (mm. erectores spinae) and the knee flexors (m. biceps femoris, m. semimembranosus, m. semitendinosus). Furthermore, it is important to point out that the Thomayer's test does not normally reveal all variants of lesion (including the discogenic one), one of the symptoms of which is limited lateral flexion or backward bending. It is also necessary to examine excessive mobility especially in the lumbosacral passage as the results of the Thomayer's test in hypermobile patients are usually negative (Lewit, 1998). What we found interesting was that none of the girls in our experimental groups (A, B) were hypermobile even though hypermobility is common in females. This may well be a consequence of the girls' sedentary lifestyle and lack of physical activity. We also assume that significant improvement ($p<0.01$) in the Thomayer's test results in both experimental groups (A, B) was reached also as a result of higher extent of motion of the pelvis around the hip joints and the fact that the girls learnt how to use this extent of motion when doing a particular exercise. This means that the test does not exclude false positive results connected with shortening of the knee flexors and that it does not necessarily show improvement in elasticity of the spine and back muscles. Inclination and control of the pelvis are important for the upper region of the sacrum, which supports the vertebrae above. Pelvic tilt in the standing position influences development of the lumbar lordosis and higher regions of the spinal vertebrae. What is more, sufficient range of motion of the pelvis around the hip joints allows the trunk to bend forward freely. Otherwise, it is necessary to bend the back and press the spine, which has an adverse effect mainly on front edges of the vertebrae (Lewit, 1998). This happened also during the initial measurements. The initial measurements of the lumbar spine mobility, which were done by means of the Schober's test, revealed abnormal development of the spine as the girls' spine curvature was not smooth. This means that their paravertebral muscles in the lumbar region were weakened. The final measurement results showed that none of the girls had this problem anymore. The values measured by the Schober's and Stibor's tests increased after completion of the exercise programme and they were all standard. We suppose that this improvement was reached not only due to a higher extent of motion of the pelvis around the hip joints, but also because of the fact that the girls learnt how to use this extent when doing a particular exercise. What is more, the final lateral flexion test results proved a positive effect of the exercise programme on the quadratus lumborum muscle, which was symmetrical. These results were in contrast to the results of the initial measurement during which we found that the flexion to the opposite side was difficult, the spine curvature was not smooth and the lumbar segment was stiff, which may lead to an increase in mobility of the thoracolumbar passage.

Conclusions

We found a significant difference ($p<0.01$) between the initial and final measurements results in all individual tests of dynamic function of the spine – Thomayers's, Schober's, Stibor's, Otto's inclination and reclination test and the lateral flexion test. What we find positive is the results of the final measurements that showed improvement in overall mobility of the spine in all the girls of both experimental groups (A, B). There were also significant statistical changes ($p<0.01$) between the initial and the continuous measurements in both groups, which is also a positive finding. We did not find any significant statistical differences between two experimental groups (A, B) as far as individual determinants of dynamic function of the spine are concerned ($p>0.05$). This means that the exercise programmes can be done efficiently by two independent groups, which is very important for future implementation of exercise programmes at schools.

We consider our findings as very important for clinical practice as well. Positive changes were made in both experimental groups in a relatively short time. If similar exercise programmes are successfully implemented in physical and sport education syllabi, they may help prevent occurrence of functional disorders of the musculoskeletal system.

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