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Research article

EFFECT OF CORRECTIVE GYMNASTICS ON MUSCLE ASYMMETRY IN PRESCHOOL CHILDREN

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Abstract. *The aim of the study is to determine the influence of developmental gymnastics intervention on muscle asymmetries along the spinal column in the sagittal plane in preschool children from Subotica. The sample consisted of 133 preschool children and was divided into three subsamples, the experimental group E1-45 (25.57%), the experimental group with additional exercise E2-45 (25.57%), and the control group K-86 (48.86%). A 10-week experimental exercise treatment was applied to two groups of participants, one of which had one additional exercise at home with their parents. Contemplas 3D Compact analysis was applied to assess muscle asymmetries (Professionalmotion analysis software) taking into account the variables related to the sagittal plane. By analyzing the results of the multivariate analysis of covariance it could be concluded that there are statistically significant differences (p = 0,03) between samples of different groups for the assessment of the parameters of the spinal column in the sagittal plane on the value of Pillai's Trace PT= 2,52 at the final measurement compared to the initial one. It can be pointed out that there are positive and visible effects of treatment on children from the experimental group, and that the program of corrective gymnastics has an impact on reducing muscle asymmetries in the sagittal plane, while the greatest effects are visible in the lumbar spine.*

Key words: *Corrective Gymnastics, Contemplas, Muscle Asymmetries*

1. INTRODUCTION

Physical activity is one of the most important methods of improving and enhancing children's health (Jin et al., 2018), while physical inactivity on the other hand negatively

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affects health homeostasis, primarily health, quality of life and social aspects of development (WHO, 2016). A high level of sedentary behavior is associated with short-term and long-term psychophysiological health consequences (Hinkley et al., 2014; Katzmarzyk et al., 2009). The *Canadian Society for Exercise Physiology, Department of Health, Physical Activity, Health Improvement and Protection and Department of Health and Aging, Australia* (2012) recommends that children during growth and development should be exposed to at least two or three hours of daily physical activity, and on the other hand, their time spent in a sedentary regime should be limited. Physical activity is very important for the undisturbed development of children (Strong et al., 2005), and accordingly it is assumed that muscle inactivity negatively affects the formation of asymmetries that can develop into more serious incorrect postures.

The physiological sagittal spinal curvature represents a typical feature of good posture in the sagittal plane. The pelvis leans forward, and the lower limb joints stay in neutral position which represents good body posture. Bad body posture can appear due to weak muscles and muscle asymmetry of the left and right, front, and back side of the body. Posture quantification is conducted by noticing minor displacements of the body's center of gravity or radiographic lateral asymmetries. (Thomkinson & Shaw, 2013, Schmid et al., 2015). Bad body posture assessment is conducted using digital photometry (Stolinski, et al., 2017) with Contemplas being one of the recognized methods. This method has been implemented on older and younger school children (Kojic, 2014; Kovac et al, 2015; Scepanović, 2017, Kapo et al, 2018).

There are various reasons for the occurrence of postural disorders in children and young people, but they most often appear in the form of idiopathic disturbed postures (Eider & Paczyńska-Jędrycka, 2014). During the preschool age and even school age, the child's posture is formed by many external influences, which lead to inadequate postural habits. Impaired posture, among other things, can occur as a consequence of reduced range of motion, i.e. all those factors that define the hypokinetic syndrome. On the other hand, good postural status, i.e. proper posture, can be defined as a state of good musculoskeletal balance that protects against the emergence and progressive development of postural disorders (Madic, 2014). However, the lack of muscle activation, logically, implies muscle weakness due to which muscle imbalances can also occur (Nosko et al., 2016). If, for example, we consider the positions of the scapular or shoulder region, the consequences may be muscle atrophy, disturbed bone contour, a lower scapular angle due to muscle inactivity, weakness and lack of strength of the rotator cuff muscles (Burkhart et al., 2003; Kibler, 2003; Kibler et al. , 2002, Meister, 2000). Prolonged sitting leads to changes in postural status, changes in the position of the head, thoracic and lumbar spine (Clausi et al., 2016), with the forward head posture. Bad life habits have a negative impact on muscle integrity, both on the length of the muscle itself (usually muscle shortening and reduced elasticity) and muscle efficiency (reduction of muscle function). One of the most effective ways to prevent the development of impaired posture is prevention – i.e. the educational process (Kutis et al., 2017), parental involvement, both in the prevention and correction of impaired posture (Mrozkowiak et al., 2016), as an adapted and properly dosed physical activity (Feng et al, 2018, Wyszyńska et al., 2016). Incidence of muscle asymmetries, i.e. disturbed postures, has been constantly increasing in recent years, and their higher frequency is reported due to the improvement of diagnostic procedures in the child population, and the use of modern detection methods and software (Kutis, 2017). Therefore, there is a need for constant screening and development of new training forms that would have an impact on prevention and correction when it comes to muscle asymmetries or impaired posture. Certain knowledge in this field can contribute to a more adequate and thorough approach in the treatment of disturbed postures.

Based on the presented facts, the research objective is set, which includes determining the efficiency of the kinesitherapy program, i.e. corrective gymnastics, with additional exercise for muscle imbalances to be performed with the parents.

2. METHOD

2.1. Participants

This is a longitudinal-type study which involved the application of a ten-week developmental gymnastics intervention on children aged 5 to 7. The total sample of children (n=133, Fig. 1) was divided into three sub-samples: experimental group E1 - 45 (25.57%), experimental group with additional exercises E2 - 45 (25.57%), and the control group C-43 (48.86%). The average age of the total sample was 6.19±0.58 years, and the participants were classified into groups by approximately the same age (p=0.83). The average age of the participants in the control group was 6.18 ±0.60, the average age in the experimental group with the intervention 6.21±0.57, and the average age of the participants in the experimental group with the intervention and additional exercises at home was 6.19±0.57 years. Two experimental interventions were implemented in groups E1 and E2. There were only 43 participants in the control group due to a smallpox epidemic in the preschool.

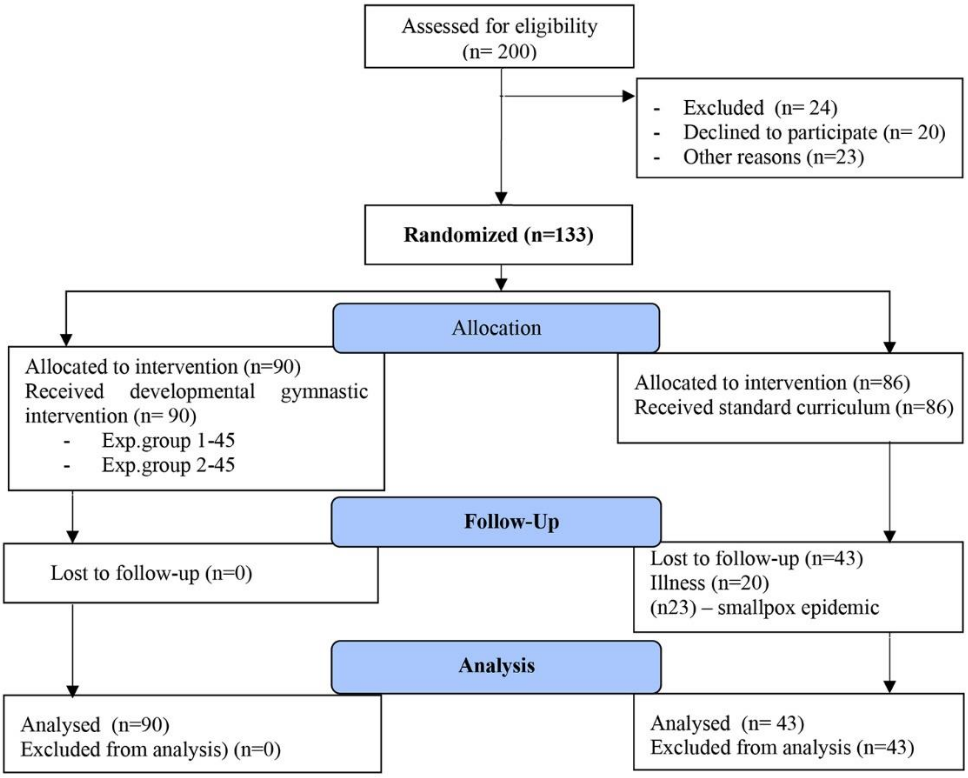

Fig. 1 CONSORT flow diagram

2.2. Procedures/testing

3D Compact analysis by Contemplas (*Professional motion analysis software*) was applied for assessing muscle asymmetries – the photometrics method. The results are obtained in the form of simple animations that give a precise picture of muscle deviations, i.e. the asymmetry of the body. Recording is done with three cameras, after which reports are received. Marking of reference points enables reading of the position of the shoulders, pelvis, body posture in the sagittal and frontal plane, as well as the position of the legs. The 3D module consists of three cameras on the basis of which a precise image of the postural status is obtained from all three perspectives, and the accuracy of the system was confirmed by the Cologne University of Sports (Scepanovic et al., 2015). The variable sample consists of 3 variables acquired by "3D posture compact" testing protocol (Table 1).

Table 1 Variables and abbreviations for 3D posture analysis

Sag. Distance cervical spine – sacrum The variable is expressed in centimeters and indicates the distance between the most protruded cervical (neck) vertebra and the projected vertical line of the sacrum (the bone at the bottom of the spine) in the sagittal plane. A positive result means a more pronounced flexion of the cervical spine, while a negative result means a more pronounced extension of the cervical spine.
Sag. Distance thoracic spine – sacrum The variable is expressed in centimeters and indicates the distance between the thoracic spine and the projected vertical line of the sacrum (the bone at the bottom of the spine) in the sagittal plane. Positive results indicate a more pronounced flexion in the thoracic spine, while negative results indicate a more pronounced other extension of the thoracic spine.*Higher positive and negative offsets do not apply to the variables.
Sag. Distance lumbar spine – sacrum The variable is expressed in centimeters and indicates the distance between the lumbar (lower) spine and the projected vertical line of the sacrum (the bone at the bottom of the spine) in the sagittal plane. A positive result means a more pronounced lumbar spine flexion, while negative results means a more pronounced lumbar spine extension.

2.3. Testing protocol

The test protocol first involves placing the Contemplas flat panel (Figure 2). In order to place it correctly, it is first necessary to find an ideally flat surface. It is necessary to fix the Contemplas panel to the substrate so that it does not move during the screening itself. After forming a flat surface, it is necessary to form a calibration 3d frame or a frame that contains reflex markers (Figure 3).

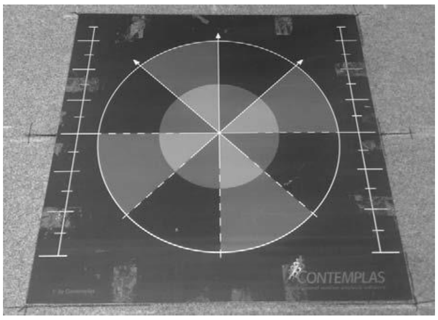

Fig. 2 Screening surface

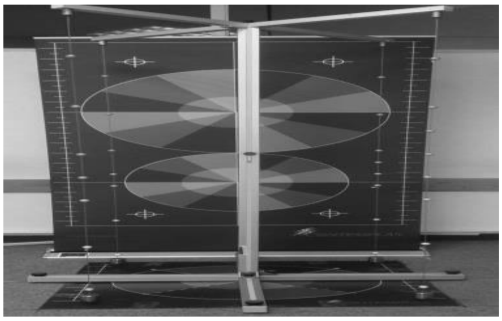

Fig. 3 Calibration frame

The complete calibration space consists of the Contemplas panel ideally aligned with the calibration frame (Figure 4). The relationship between these two segments must be ideally aligned, which is checked by using a spirit level. After the formation of the calibration space, 3 cameras are installed that enable three-dimensional analysis.

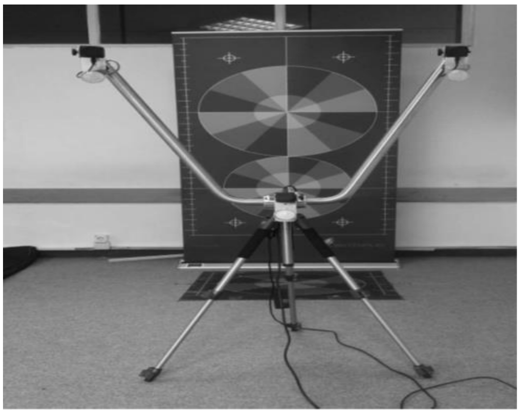

Fig. 4 V Camera Frame

The distance of the camera from the screening surface should be at least two meters. The screening process begins by checking the image quality on the software and after that the camera starts calibrating the space. The next step involves marking the participant at precisely defined specific points on the body (Figure 5).

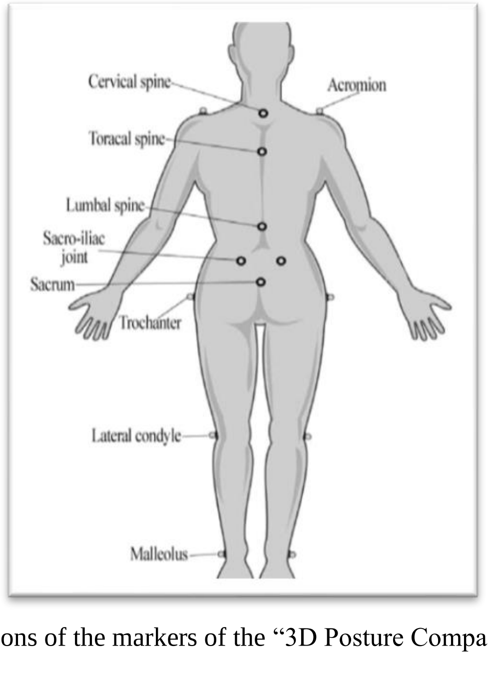

Fig. 5 Positions of the markers of the “3D Posture Compact” protocol

2.4. Training program

The E1 module included a 10-week experimental intervention and included two individual 45-minute interventions weekly managed by the author of this study. The intervention included the developmental gymnastics treatment designed to treat primarily the antigravity muscles, but also motor coordination and postural stability. The E2 module included a separate part of the intervention which was implemented by the children's parents at home, and added to the Module 1 settings. The additional 20-minute intervention was realized at home, two times a week. The parents were previously trained and provided with an exercise plan which they followed during the intervention, and recorded it on a regular basis in a log prepared by the author. The goal of the intervention was to equally strengthen the back muscles including the lower back muscles and the shoulder and scapula muscles. The intervention was not applied to the control group. During the intervention, the E1 group performed 20 individual exercise units (module 1), whereas the E2 group performed 20 exercise units from Module 1 and 20 additional exercise units of Module 2. All the exercises were designed to lead to a positive transfer and, since the children are of the preschool age, the classes were divided into the following four parts: introductory, basic, main, and final section. Each part was envisaged according to the plan and as a continuation of the previous class.

2.5. Intervention programs

The E1 module (Table 2) implied an experimental intervention lasting ten weeks and included two individual interventions of 45 minutes during a week which were managed by the author of this paper. The intervention implied the application of developmental gymnastics contents designed to treat primarily the antigravity muscles, motor coordination and postural stability as well (Table 2). We used the Borg rate of perceived exertion (RPE) scale (1–10) and asked each participant to provide their overall RPE for the session. It was shown previously that children, even as young as 5–6 years of age, can become quite adept at rating their perceived exertion. The E1 program was organized in the form of frontal, group work but mostly as circuit training (polygon) or repetitive (station) training. If the exercise was performed within the polygon, the children were to do the task and move to the next station. Obstacles consisted of various gymnastic apparatus and props for solving motor problems made up of gymnastic and athletic exercises, as well as elementary games. Station training was made up of repeating the same exercises more than once on one station (e.g., one gymnastic apparatus). In this case, the exercise was repeated. In order to increase the intensity of the exercises and reduce the waiting for the apparatus for exercise, some exercises with additional and complementary tasks were added (e.g., exercises for strengthening and stretching, as well as exercises on supplementary apparatus).

Table 2 E1 module: The structured exercise program

Duration	Organization	Volume	Frequency	Intensity
10 weeks	Frontal work, group work, group with stations, polygon and circuit work	45 minutes per session	2 times a week	According to external signs (sweat, flush, spontaneous break

The training structure: a 10-minute warm-up consisted of various natural forms through play which aimed at raising the children's functional capacities. The 30-minute main part was conducted through exercises aimed at the development of motor abilities, anthropometric and morphological elements strengthening the muscle system. The 5-minute cool-down part was comprised of a combination of stretching exercises on Swedish ladders, fitness balls, and mats.

The E2 module (Table 3) was designed to include a separate part of the intervention implemented by the children's parents at home, in addition to Module 1. The additional intervention was realized at home, for 20 minutes twice a week (Table 3) The previously trained parents were provided with the curriculum they followed during the intervention and regularly recorded it in a log given by the author. The intervention was aimed at strengthening the muscles of the back including the lower back muscles and the muscles of the shoulder and scapula region equally represented.

Table 3 E2 module: The structured exercise program

Duration	Organization	Volume	Frequency	Intensity
10 weeks	Individual work,	20 minutes per session	2 times a week	According to external signs (sweat, flush, spontaneous break

The control group was not part of the treatment in the preschool and only had non-structured physical activity and play in their free time.

2.6. Statistical analysis

The statistical software SPSS Statistics for Windows, version 20 was used for statistical data processing. All collected data were processed by descriptive and comparative statistics procedures. The statistical method of data processing determined the basic descriptive statistics of variables: arithmetic means (AM), standard deviation (S), coefficient of variation (CV) of the initial and final screening, separately for all three groups of participants. The normality of the distribution was checked using the Shapiro-Wilk test for small samples at the significance level of $p \leq 0.05$. Multivariate analysis of variance (MANOVA) was used to determine differences in the entire posture space at the initial and final measurements, and One-Way ANOVA was used to determine individual differences. The effects of the treatment were determined by multivariate analysis of covariance (MANCOVA) and univariate analysis of covariance (ANCOVA). After determining significant differences between the groups of participants using the Bonferroni comparison, an attempt was made to determine between which groups real differences could be found. Due to an uneven number of participants, Pillai's Trace statistic was used.

3. RESULTS

3.1. Descriptive statistics of variables analyzed in initial screening depending on the group

Descriptive statistics of variables of the spinal column in the sagittal plane at the initial screening in all three analyzed groups (Table 4) indicate exceptional heterogeneity of the results with significant individual differences. The parameters of the spinal column in all three groups have a normal distribution.

Table 4 Descriptive statistics of variables of the spinal column in the sagittal plane at the initial screening of different groups

Variable	Control (N=37)			Experimental 1 (N=22)			Experimental 2 N=41		
	AM±S	CV	SWp	AM±S	CV	SWp	AM±S	CV	SWp
Cervical lordosis (cm)	0.84±3.01	27.91	0.51	0.89±2.03	43.84	0.43	1.69±2.91	58.08	0.60
Thoracic kyphosis (cm)	-2.12±3.09	68.61	0.59	-1.41±1.54	91.55	0.58	-1.12±3.26	34.36	0.11
Lumbar lordosis (cm)	0.36±2.20	16.36	0.46	1.35±1.95	69.23	0.61	0.92±1.83	50.27	0.67

Legend: C - control group, E1 - experimental group with treatment; E2 - experimental group with treatment and additional exercise at home; AM - arithmetic mean; S - standard deviation; CV - coefficient of variation; SWp - level of statistical significance of Shapiro Wilk coefficient

Descriptive statistics of variables of the spinal column in the sagittal plane at the final screening (Table 5) in all three analyzed groups indicate exceptional heterogeneity of the results with significant individual differences. In all other analyzed variables, a normal distribution of the results is observed.

Table 5 Descriptive statistics of the variables of the spinal column in the sagittal plane at the final screening of different groups

Variable	Control (N=37)			Experimental 1 (N=22)			Experimental 2 N=41		
	AM±S	CV	SWp	AM±S	CV	SWp	AM±S	CV	SWp
Cervical lordosis (cm)	0.81±2.91	27.84	0.08	0.57±2.46	23.17	0.29	0.76±1.71	44.44	0.40
Thoracic kyphosis (cm)	-2.06±2.38	86.55	0.13	-1.96±1.94	101.03	0.71	-1.25±1.54	81.17	0.52
Lumbar lordosis (cm)	1.65±2.02	81.68	0.48	1.90±2.79	68.10	0.54	1.05±0.91	115.38	0.78

Legend: C - control group, E1 - experimental group with treatment; E2 - experimental group with treatment and additional exercise at home; AM - arithmetic mean; S - standard deviation; CV - coefficient of variation; SWp - level of statistical significance of Shapiro Wilk coefficient

3.2. Differences between groups at initial screening

By analyzing the results of multivariate analysis of variance (Table 6), it can be concluded that there are no statistically significant differences (p=0.38) between the participants from the experimental groups and control group in the variables used for assessment of the spinal column in the sagittal plane with a PT test value of 1.08. Prior to the application of the treatment, no statistically significant differences were found between the groups in the parameters of the spinal column in the sagittal plane.

Table 6 Differences between participants from different groups in the parameters of the spine in the sagittal plane - initial screening

Variable	f	P	PT	P
Cervical lordosis	1.09	0.34	1.08	0.38
Thoracic kyphosis	1.20	0.31		
Lumbar lordosis	1.80	0.17		

Legend: f - univariate f test; p - level of statistical significance of the f test; PT - multivariate Pillai's Trace test; p - statistical significance of multivariate PT test

3.3. Differences between groups at the final screening

By analyzing the results of multivariate analysis of variance (Table 7), it can be concluded that there are no statistically significant differences (p=0.07) between the experimental groups and control group in the variables used for assessment of the spinal column in the sagittal plane at PT test value 1.98 at the final screening. No statistically significant differences were found in the entire region of the spinal column, but also no individual differences.

Table 7 Differences between subjects from different groups in the parameters of the spine in the sagittal plane - the final screening

Variable	f	p	PT	P
Cervical lordosis	0.05	0.95	1.98	0.07
Thoracic kyphosis	1.59	0.21		
Lumbar lordosis	1.47	0.24		

Legend: f - univariate f test; p - level of statistical significance of the f test; PT - multivariate Pillai's Trace test; p - statistical significance of multivariate PT test

3.4. Effects of treatment on parameters of the spinal column in the sagittal plane

By analyzing the results of the multivariate analysis of covariance (Table 8), it can be concluded that there are statistically significant differences (P=0.03) between the participants from the experimental groups and control group in the variables for estimating the parameters of the spine in the sagittal plane.

By equalizing the participants before the application of treatment and by individual observations, it can be concluded that these differences were found to the statistically significant extent only in the variable *Lumbar lordosis* (p=0.02) (Table 8).

Table 8 Multivariate analysis of covariance for the analyzed variables (MANCOVA)

Factor	Variable	f	p	Group	AM*	PT	P
Group	Cervical lordosis	0.10	0.90	C	0.75	**2.48**	**.03**
				E1	1.13		
				E2	0.76		
	Thoracic kyphosis	1.96	0.15	C	-2.18		
				E1	-1.19		
				E2	-1.25		
	Lumbar lordosis	**3.96**	**0.02**	C	1.58		
				E1	2.68		
				E2	0.98		

Legend: E1 - experimental group with treatment, E2 - experimental group with treatment and additional exercise at home, C - control group; f - univariate f test; p - level of statistical significance of the f test; PT - Pillai's Trace test; p - statistical significance of multivariate PT test; AM* - adjusted arithmetic mean

In order to determine the real differences between the groups, the Bonferroni comparison (Table 9) was applied on a more sensitive criterion ($p \leq 0.0167$). The Bonferroni comparison was applied to determine the real differences between the groups. Based on it, it is concluded that there are no statistically significant differences between groups on the more sensitive criterion ($p \leq .0167$), but that the treatment gave positive effects, because lower average values of the analyzed variable in the lower part of the spinal column in the sagittal plane were observed. The largest differences in arithmetic means were found between the experimental group (E1) and the experimental group that exercised additionally at home (E2) in favor of the experimental group E2.

Table 9 Real differences between groups

Dependent Variable	(I) Group	(J) Group	AM difference (IJ)	p
Lumbar lordosis final	E1	C	1.10	0.253
		E2	1.70	0.024
	C	E2	.59	0.621

Legend: E1 - experimental group with treatment, E2 - experimental group with treatment and additional exercise at home, C - control group; p - level of statistical significance

4. DISCUSSION

The critical time point for the occurrence of muscle asymmetries, and even spinal deformities, in the period of growth and development of a child, is the juvenile period from 4 to 7 years of age, which can be marked as the time period when it is necessary to pay special attention to possible muscle asymmetries. The aim of the study was to determine the effectiveness of the training content, which was composed of elements of developmental gymnastics (E1 module), as well as elements of standard kinesitherapy exercises that treat the muscles of the spine (E2 module). The research was conducted on a sample of preschool children.

The analysis of the obtained results shows that the postural status of the spinal column in the observed sample of participants before treatment was disturbed, especially the thoracic segment of the spinal column. The initial screening did not show statistically significant differences in the postural status of the spine in the sagittal plane, but there was a significant negative trend in favor of increasing the curvature of thoracic kyphosis and lumbar lordosis to the extent that it deviates from normal physiological values. The results can be explained by the fact that the level of physical activity of children is reduced already in the preschool age, which can contribute to a greater occurrence of postural poor posture and muscle asymmetries. This confirmed the results of the research of Koroljev et al. (2015) who, with the help of the same research method, determined the existence of postural deviations in the sagittal plane on a similar sample of participants, with asymmetries (changes) in the thoracic spine also predominating. The described values of results in variable *Thoracic kyphosis* at the initial screening are quite similar to the results of research by Koroljev et al. (2015). The greatest similarity of results is observed in the experimental group with treatment (E1), because in the study of Koroljev et al. (2015), the average value of thoracic kyphosis was -1.40 cm, and in the mentioned group -1.41 cm. Compared to the results of the control group, the results were on average worse in relation to the mentioned research (even on average worse by 1.51 cm). The experimental group with treatment (E2) recorded on average better (lower) values in the thoracic spine of -1.12 cm in relation to the stated results of the research of Koroljev et al. Results for the variable *Cervical lordosis* were quite similar to the results of Koroljev et al. (2015), except in comparison with the experimental group that also exercised at home, which had much greater asymmetries in this segment of the spine (1.69 cm compared to 0.95 cm). For the variable *Lumbar lordosis*, comparing the results with the results of the research of Koroljev et al (2015), better average results in the control and experimental group with treatment (E2) were observed (1.17 cm on average observed in the mentioned study), and worse average results in the group with treatment only (E1). The above research results before treatment (initial state) and the position of the marked points of the spine in the sagittal plane indicate certain muscle asymmetries that already in the preschool period take the form of an increase in cervical lordosis, thoracic kyphosis, and lumbar lordosis.

The results of the current study indicated the fact that there are statistically significant differences between the participants from the experimental groups and control group in the variables for assessing the parameters of the spine in the sagittal plane with the greatest effects in the lumbar region, with visible positive effects of treatment on the experimental group of children who exercised at home. Experimental group 1 did not make progress in all three spinal column variables because they were not under the kinesiotherapy treatment, but instead conducted the development gymnastics program, while E2 had the development gymnastics treatment together with specific kinesiotherapy exercises which engaged the spinal column muscles and activated the lumbar spinal part with every move more and cervical and thoracic part less. E2 still made more progress than E1 in the cervical spinal part (E2 initially 1.69 to 0,76 finally), although with no statistically significant difference. Comparison of the results from this research with the results for participants of a similar age obtained by a group of authors Scapanovic, Marinkovic, Korovljev and Madic (2015) where the sample was composed of 416 female participants, 7.68 years old on average, shows significantly lower average values in children from Subotica in two of the three analyzed variables of the spine in the sagittal plane. These are cervical and lumbar lordosis, where on average lower values were recorded than in the mentioned research, in two or three groups of participants. In the research by Scepanovic et al (2015), the average value was 1.83 cm for the variable *Cervical lordosis*, which is much higher than in the control group (0.84 cm), the experimental group with treatment (0.89 cm), and the experimental group with treatment and additional exercise at home (E2) where the average value at the initial screening was 1.65 cm. Lower average values with the same sign in the variable *Lumbar lordosis* were also found. The increase in the curvature of the spinal column can be explained by the fact that the participants in the research by Scepanović et al. (2015) were on average older and that the neck and lumbar curvature increased with age and the thoracic curvature of the spine decreased. Such results can be justified only by the age of the children, because the participants from Subotica were almost a year younger. An increase in cervical and lumbar lordosis has been confirmed in previous studies on a similar sample of participants (Protic-Gava et al., 2009). The decrease in chest curvature can be explained by the displacement of the center of gravity of the body forward, which is a consequence of the shifted position of the head. Recent clinical research shows a noticeable shift of the head forward, and thus the entire upper part of the body shifts forward. The pelvis leans forward, which implies an increase in lumbar curvature, which creates compensation, and at the same time an equilibrium position.

Contrary to the results of Scepanović, Marinkovic, Madic and Protic-Gava (2017), where the developmental gymnastics treatment of the muscle asymmetry and correction of poor posture lasted 12 weeks and no statistically significant improvements were observed, the results of this study showed that a 10-week treatment in a home setting can still lead to improvement in the condition of the lower back muscles. The changes were positive, but the greatest effects were achieved in the lumbar segment of the spine. Obviously, the parents, with their influence, managed to motivate the children to actively exercise, as recommended by experts. Accordingly, it can be stated that the experimental treatment contributed to the reduction of muscle asymmetries in the lumbar region, i.e. caused some corrections in the form of reduction of deviations in the specified region of the spine in the sagittal plane in the experimental group under additional treatment, i.e. exercise at home. It is well known that lumbar lordosis is most often corrected by changing the position of the pelvis in the sagittal plane, so the achieved changes are the result of good pelvic positioning during exercise, and at the same time strengthening the deep abdominal muscles and back muscles, thus achieving muscle recalibration. By activating and strengthening the deep muscles of the abdomen and the lumbar region of the back, the activation of the superficial muscles, which is directly responsible for creating an excessive lumbar lordotic curve, is reciprocally reduced. Suboptimal activation of the diaphragm, pelvic floor, transverse abdominal muscle, as well as oblique abdominal muscles, will lead to excessive activation of superficial muscles of a given region, which will try to compensate for deep muscle inactivity and stabilize the lumbar spine. As the superficial muscles are longer, and thus cross over more segments of the spine or even other bones (e.g. *m. Iliopsoas*), their stabilization and reduced activation led to a change in the statics of the lumbar spine and pelvis, and thus increased lumbar lordosis.

Inability of posture to adequately resist either internal or external forces is described by a prevalence of up to 65% (Gh Maghsoud et al., 2012; Kratěnová et al., 2007; Wirth et al., 2012). According to such indicators, it is assumed that the weakened muscles are more susceptible to the acute effects of a ten-week treatment, and that the effects of the treatment were more pronounced due to more regular muscle toning that takes place under the control of the parents. There is also the fact that the participants from the control group and the experimental group that exercised in kindergarten may have had insufficient physical activity during the day which can lead to an increase in lumbar and other curvatures of the spine in this period of life (Ho Ting Yip, Tai Wing Chiu and Tung Kuen Poon, 2008).

The absence of results in the cervical and thoracic spine can be attributed to the insufficient specificity of the exercises for this region, since the musculature of the ventral side of the neck is not significantly affected by these exercises. Upright posture, i.e. centering of the cervical spine, is possible only if there is activation of its ventral aspect, i.e. *m. longus colli* and *m. longus capitis* as an addition to dorsal musculature activation (Kolar, 2006). On the other hand, the presence of positive results in the lumbar region can be attributed to the continuous activation and strengthening of the core muscles, which has a direct impact on the stabilization of the spine (Kibler et al., 2006). The reduction in lumbar lordosis due to the activation of the core muscles is most likely a consequence of the creation of intra-abdominal pressure, which occurs when all the core muscles are activated at the same time. Coactivation of the diaphragm, pelvic floor and abdominal muscles creates intra-abdominal pressure. Negative pressure in the abdomen does not allow translational movement of the spine forward and thus prevents excessive lordotic position of the lumbar spine. The interaction between the IAP and the spinal extensor fixes the spinal column and the pelvis. In physiological conditions, where there is such an interaction, the joints of the lumbar spine are in a centered position during the activation of the muscles of the upper and lower extremities, which means that when activating the muscles of the extremities, there will be no movement and decentration between the lumbar vertebrae, and thus there will be no excessive lumbar lordosis.

The fact that there are no statistically significant differences between group E2 and group C that was not treated indicates that versatile physical activity also has a very significant impact on postural status. If we look at muscle imbalance through the neurological paradigm (Paige, 2009), i.e. that muscle imbalance is a consequence of reduced movement, as well as reduced diversity of movement, it is clear that even nonspecific exercise, which includes standard activities such as jumping, running, prolonged squatting, has an impact on a harmonious and balanced muscular, and thus skeletal system. The control group performed standard activities that were not programmed to treat specific musculature, which again indicates the fact that versatile physical activity can also have an impact on a harmonious and balanced muscular system (Karaleic et al., 2014). There was no deterioration of the results compared to the initial state, which leads to the conclusion that positive effects of exercise were observed in all three groups of participants. But it should be noted that better results are achieved by targeted action and treatment on target regions and body parts in preschool children, mostly on the lumbar spine.

5. CONCLUSION

The effects of the treatment can be characterized as positive and successful on a sample of preschool participants. The very fact that there was an improvement in the position of lumbar lordosis and thus an improvement in sagittal balance shows us that the treatment had a significant effect on children who exercised additionally at home. The application of 3d analysis proved to be very demanding on a population of preschool children. Namely, even the smallest muscle contraction or change of position of a body segment at the moment of imaging in the 3d protocol analysis can have an impact on the obtained results, and must be approached thoroughly and very precisely. The recommendation for further research would be to consider the effects of developmental gymnastics on the sagittal plane as well.

The obtained research results expand the theoretical picture of the application and frequency of exercise in preschool children and its impact on muscle imbalances and asymmetry. From a practical point of view, it is possible to implement the results of this work in a regular preschool program. The realization of this research contributes to the scientific community as a basis for further research, the possibility of comparing data and expanding scientific material. This paper could also contribute to anthropological disciplines such as kinesitherapy, biomechanics, by analysis of the state of certain anthropological dimensions of children with more pronounced asymmetries in the sagittal plane.

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EFEKAT KOREKTIVNE GIMNASTIKE NA MIŠIĆNE ASIMETRIJE KOD DECE PREDŠKOLSKOG UZRASTA

Cilj studije je da se utvrdi uticaj korektivne gimnastike na mišićne asimetrije na nivou kičmenog stuba u sagitalnoj ravni kod dece predškolskog uzrasta iz Subotice. Uzorak je činio 133 dece predškolskog uzrasta i bio je podeljen na tri subuzorka, eksperimentalnu grupu E1-45 (25.57%), experimentalnu grupu sa dodatnim vežbanjem E2-45 (25.57%) i kontrolnu grupu K-43 (48.86%). Primenjen je eksperimentalni tretmana vežbanja u trajanju od 10 nedelja na dve grupe ispitanika, od kojih je jedna imala i još jedno dodatno vežbanje kod kuće sa roditeljima. Za procenu mišićnih asimetrija primenjena je 3D Compact analiza marke Contemplas (Professional motion analysis software) gde su uzete u obzir varijable koje se odnose na sagitalnu ravan. Analizom rezultata multivarijatne analize kovarijanse može se zaključiti da postoje statistički značajne razlike (p=0.03) između ispitanika eksperimentalnih i kontrolne grupe u varijablama za procenu parametara kičmenog stuba u sagitalnoj ravni pri vrednosti Pilar' s Trace koeficijenta PT=2.52. Može se istači da postoje pozitivni i vidljivi efekti tretmana na eksperimentalnoj grupi dece i da je program korektivne gimnastike uticaj na smanjenje mišićnih asimetrija i sagitalnoj ravni, a najveći efekti su vidljivi u lumbalnom delu kičmenog stuba.

Ključne reči: *korektivna gimnastika, contemplas, mišićne asimetrije*