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ABSTRACT

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THE IMPACT OF SYMMETRICAL VS. ASYMMETRICAL THERAPEUTIC EXERCISES ON POSTURAL ALIGNMENT AND TRUNK MUSCLE ENDURANCE IN CHILDREN WITH MILD SCOLIOSIS

Introduction. Scientific research has proven that therapeutic exercises provide an opportunity to achieve significant success in physical therapy for scoliosis in children. Both symmetrical and asymmetrical therapeutic exercises are used in rehabilitation interventions. In Ukraine, the rehabilitation package of the National Health Service of Ukraine (NHSU) provides physical therapy services for children with mild scoliosis (1-2 degree) for two weeks. However, the question of the impact of different types of therapeutic exercises in a two-week physical therapy programme remains open.

Aim. This study aims to determine the effect of symmetrical and asymmetrical exercises on posture and strength of the abdominal muscles and back extensor strength in 10-12 year old children with mild scoliosis during a two-week physical therapy programme according to the NHS rehabilitation package.

Materials and methods. The study included 25 patients aged 10-12 years, including 12 boys and 13 girls with diagnosed degenerative-dystrophic changes of the spine, namely S-shaped thoracolumbar scoliosis of the 2nd degree with different curvature angles (from 10 to 25° according to Cobb) or mild degree. All patients were divided into 2 groups, regardless of age and gender: a group of 11 people who participated in a physical therapy programme based on symmetrical therapeutic exercises, group training; a group of 14 people who participated in a physical therapy programme based on asymmetrical therapeutic exercises, individual training. At the beginning and at the end of the study, a survey was conducted, which included: New York Posture Rating Chart (NYPR) to assess posture in the frontal and sagittal planes, Adams test to assess posture in the horizontal plane, standardised

functional tests to assess abdominal muscle strength and back extensor strength, height and weight measurements, and BMI calculation. An X-ray examination of the spine with the calculation of Cobb's angle and Risser's test score was performed only at the beginning of the study.

The STATISTICA 6.0 software package was used for statistical processing of the study results. The probability level was taken as $p < 0.05$.

Results. There is a decrease in postural asymmetry and an increase in functional endurance of the abdominal muscle strength and back extensor strength, regardless of gender and physical therapy programme, which confirms the success of different types and forms of therapeutic exercises to stabilise the muscular corset and reduce postural asymmetry. It should be noted that the SymG group showed more positive, but not significant, dynamics of functional indicators, but the only indicator, namely the NYPR posture score, was significantly improved in the AsymG.

Conclusions. The use of an individual approach and asymmetrical exercises has a significantly better effect on postural symmetry, which indicates the feasibility of personalised development of physical therapy programmes for patients with more severe deformities of the posture and spine.

Keywords: scoliosis, physical therapy, therapeutic exercises, posture, muscle strength, children.

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ВПЛИВ СИМЕТРИЧНИХ VS АСИМЕТРИЧНИХ ТЕРАПЕВТИЧНИХ ВПРАВ НА ВИРІВНЮВАННЯ ПОСТАВИ ТА СИЛУ М'ЯЗІВ ТУЛУБА У ДІТЕЙ З ЛЕГКИМ СТУПЕНЕМ СКОЛІОЗУ

Вступ. Науковими дослідженнями доведено, що терапевтичні вправи надають можливість досягати значних успіхів у фізичній терапії при сколіозі у дітей. Серед реабілітаційних втручань застосовуються як симетричні, так і асиметричні терапевтичні вправи. В Україні реабілітаційний пакет Національної служби здоров'я України (НСЗУ) передбачає надання послуг фізичної терапії для дітей із легким ступенем (1-2 ступінь) сколіозу протягом двох тижнів. Але питання впливу різних типів терапевтичних вправ при двотижневій програмі фізичної терапії залишається відкритим.

Мета. Це дослідження має визначити вплив симетричних та асиметричних вправ на поставу та силу м'язів черевного пресу і розгиначів хребта дітей 10-12 років зі сколіозом 2 ступеня при двотижневій програмі фізичної терапії за реабілітаційним пакетом НСЗУ.

Матеріали і методи. У дослідженні брали участь 25 пацієнтів віком 10–12 років, з них 12 хлопчиків та 13 дівчаток із діагностованими денегеративно-дистрофічними змінами хребта, а саме S-подібним грудо-поперековим сколіозом 2 ступеня з різними кутами викривлення (від 10 до 25° за Коббом). Усі пацієнти були поділені на 2 групи незалежно від віку та статі: група з 11 осіб, які брали участь у програмі фізичної терапії, що розроблена на основі симетричних терапевтичних вправ, форма заняття – групова; група з 14 осіб, які брали участь у програмі фізичної терапії з асиметричних

терапевтичних вправ, форма занять – індивідуальна. На початку та наприкінці дослідження було проведено обстеження, що включало: New York Posture Rating Chart (NYPR) для оцінки постави у фронтальній та сагітальній площинах, тест Адамса для оцінки постави у горизонтальній площині, стандартизовані функціональні тести для оцінки сили м'язів черевного пресу та м'язів розгиначів хребта, вимірювання зросту, ваги, розрахунок ІМТ. Рентгенологічне дослідження хребта з розрахунком кута Кобба і показника за тестом Ріссера проводилося лише на початку дослідження.

Для статистичного опрацювання результатів дослідження застосовувалося пакетне забезпечення STATISTICA 6.0. Рівень вірогідності прийнятий $p < 0,05$.

Результати. Спостерігається зменшення асиметрії постави та збільшення функціональної витривалості м'язів черевного преса та розгиначів хребта незалежно від статі та програми фізичної терапії, що підтверджує успішність різних типів та форм занять терапевтичними вправами для стабілізації м'язового корсету і зменшення асиметрії постави. Слід зазначити, що у групі СимГ спостерігалася більш позитивна, але не суттєва динаміка функціональних показників, але єдиний показник, а саме оцінка постави за Нью-Йоркським тестом класифікації постави тіла, вірогідно більше покращився у АсимГ.

Висновки. При застосуванні індивідуального підходу та асиметричних вправ виявлений вірогідно кращий вплив на симетричність постави, що свідчить про доцільність персоналізованого розроблення програм фізичної терапії для пацієнтів із більш вираженою деформацією постави і хребта.

Ключові слова: сколіоз, фізична терапія, терапевтичні вправи, постава, сила м'язів, діти.

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ABBREVIATIONS

AsymG – Asymmetric Exercise Group
NHSU – National Health Service of Ukraine
NYPR – New York Posture Rating scale
SDGs – Sustainable Development Goals
SymG – Symmetric Exercise Group

INTRODUCTION

Among the Sustainable Development Goals in the context of physical therapy is Goal 3 «Ensure healthy lives and promote well-being for all at all ages», the essence of which is expressed as «Good health and well-being» [1]. Achievement of all the SDGs depends on the health of the labour population. Therefore, caring for children's health is extremely relevant and necessary in the post-conflict realities of Ukraine. Particular attention should be paid to the prevention of the progression and development of musculoskeletal disorders, including scoliosis, due to the long-term negative consequences for physical health and quality of life in adulthood.

According to the Centre for Medical Statistics of the Ministry of Health of Ukraine, one in four children has postural disorders; during the latest preventive examinations in 2020, 231,422 children with such disorders were identified, including 92,322 cases of scoliosis [2].

There are many rehabilitation schools whose methods focus on the use of corrective therapeutic exercises in three areas. Today, the most recognised in Europe are: SEAS (Scientific Exercises Approach to Scoliosis) [3], Schroth Method [4]. Data confirming the reliability of other methods are somewhat limited. However, scientific studies have shown that therapeutic exercises provide an opportunity to achieve significant success in physical

therapy for scoliosis in children [5]. Among rehabilitation interventions, both symmetrical and asymmetrical therapeutic exercises are used. However, the question of the impact of different types of therapeutic exercises remains open. The aim of our study is to determine the effect of symmetrical and asymmetrical exercises on posture and strength of the abdominal muscles and back extensors in children aged 10-12 years with mild scoliosis.

MATERIALS AND METHODS

The study was based on the Chernihiv Regional Children's Hospital, Department of Rehabilitation and Physical Therapy. Patients received a physical therapy programme for two weeks in accordance with the National Health Service of Ukraine (NHSU) package. The parents of the children signed an informed voluntary consent for the treatment and rehabilitation of their children and permission to participate in the study and statistical processing of the results. The study protocol was reviewed and approved by the Bioethics Committee for Academic and Clinical Research of the Educational and Scientific Medical Institute of Sumy State University (Protocol No. 4/02, February 18, 2025).

The study involved 25 patients aged 10-12 years, including 12 boys and 13 girls with diagnosed degenerative-dystrophic changes of the spine, namely S-shaped thoracolumbar mild scoliosis with different curvature angles (from 10 to 25° according to Cobb).

All patients were divided by a physician of physical and rehabilitation medicine into 2 groups regardless of age and gender: group training group (SimG), which included 11 people, namely 7 girls and 4 boys, who participated in a physical therapy programme based on symmetrical therapeutic exercises; individual training group (AsymG), which included 14 people, namely 7 girls and 7 boys, who participated in a physical therapy programme based on asymmetrical therapeutic exercises.

All participants were assigned by a physical and rehabilitation medicine physician into two groups, regardless of age or sex:

- the Group Exercise Group, which included 11 participants (7 girls and 4 boys) who underwent a physical therapy program based on symmetric therapeutic exercises (SymG);
- the Individual Exercise Group, which included 14 participants (7 girls and 7 boys) who received a physical therapy program consisting of asymmetric therapeutic exercises (AsymG).

The general characteristics of participants and their morphological and functional indicators are given in Table 1. It should be noted that the groups differed in terms of Cobb angle and posture score according to the New York Posture Rating scale (NYPR). Specifically, the Cobb angle was significantly lower, and the posture score slightly better, in the SymG compared to the AsymG. These findings indicate a more complex clinical condition in the AsymG. Therefore, when analyzing the effects of therapeutic exercises, the primary focus will be on the changes in outcome measures before and after the intervention. Moreover, considering that the Cobb angle is unlikely to change within a two-week period [5], it is deemed appropriate to compare other variables between groups that did not significantly differ at baseline.

Table 1. General Characteristics of the Participants and Their Morphofunctional Indicators at Baseline, M ± SD

Variables	*All n=25*	*Boys n=11*	*Girls n=14*	*SymG n=11*	*AsymG n=14*
Age, years	11,44±0,71	11,73±0,65	11,21±0,70	11,45±0,52	11,42±0,85
Height, cm	156,12±5,64	157,36±3,32	155,14±6,92	157,54±1,96	155±7,25
Weight, kg	48,88±4,63	48,64±4,70	49,07±4,75	49,54±2,94	48,35±5,67
BMI, kg/m²	20,04±1,43	19,60±1,26	20,39±1,50	19,96±1,28	20,10±1,58
Cobb angle, degrees	17,08±4,84	17,00±5,46	17,14±4,50	14,18±2,85	19,35±4,92*
Risser test, points	2,20±0,50	2,27±0,65	2,14±0,36	2,18±0,60	2,21±0,42
Adam`s Forward Bend Test, points	1,96±0,20	2,00±0,00	1,93±0,27	2,00±0,00	1,92±0,26
Abdominal muscle strength, reps/min	11,08±3,04	9,82±2,04	12,07±3,38	11,27±2,57	10,92±3,45
Back extensor strength, sec	65,28±26,71	64,55±28,41	65,86±26,36	65,18±25,28	65,35±28,72
New York Posture Rating scale, points	17,80±1,55	18,18±1,54	17,50±1,56	16,90±0,83	18,5±1,65*

Note: $p < 0.05$ indicates a statistically significant difference between the Symmetric Exercise Group (SymG) and the Asymmetric Exercise Group (AsymG)

At the beginning and at the end of the study, participants underwent an assessment that included the NYPR to evaluate posture in the frontal and sagittal planes, the Adam`s Forward Bend Test for assessing posture in the horizontal plane [6], standardized functional tests to evaluate abdominal muscle strength and back extensor strength, as well as measurements of height, weight, and body mass index (BMI). Radiographic examination of the spine, including the Cobb angle measurement and Risser test score (used to assess skeletal maturity based on the ossification of the iliac crest in children and adolescents), was performed only at the beginning of the study, due to the potential adverse effects of repeated X-ray exposure [7, 8].

To investigate the strength of the muscles of the subjects, tests of strength endurance of the abdominal muscles and the strength of the back extensor muscles were used. To determine the strength endurance of the abdominal muscles, the child takes a supine position on the couch, arms along the body. From this position, the child should move to a sitting position without bending the legs and without taking them off the couch, then return to the starting position. The number of torso lifts per minute is counted. To assess the strength of the back extensor muscles, the child lies face down on the couch so that the upper body up to the iliac crest is hanging in front of the couch, arms on the belt (the legs are held by the physical therapist). The patient lifts the torso as much as possible and remains in this position until fatigue. The time to complete muscle fatigue is determined by a stopwatch [9].

Symmetrical and asymmetrical therapeutic exercises have been used in physical therapy programmes. These are corrective therapeutic exercises that help to correct spinal deformities by generating muscle traction directed opposite to the defect. When performing symmetrical therapeutic exercises, the midline position of the vertebrae is maintained, while the muscles on both sides of the body contract unevenly. The exercises are based on training the extensor muscles of the spine, where stretched and weakened muscles contract more, and tense muscles contract less. Asymmetrical therapeutic exercises are aimed at training only weakened and stretched back muscles. When performing them, an appropriate position is selected that acts on a specific part of the spine to reduce curvature arcs that are far apart (for example, one in the thoracic spine and the other in the lumbar spine).

The STATISTICA 6.0 software package was used for statistical processing of the study results. The level of probability was taken as $p < 0.05$. The probability of difference of indicators by sex and between groups was carried out by Student's t-test for independent pairs, comparison of indicators after the physical therapy programme – by Student's t-test for dependent variables.

RESULTS

After a two-week physical therapy programme, the examination and evaluation of the studied indicators (except for radiography for Cobb angle and Rieser's test) were carried out, which are presented in Table 2.

Table 2. Characteristics of the Assessed Morphofunctional Indicators After a Two-Week Physical Therapy Program, M±SD

Variables	*All n=25*	*Boys n=11*	*Girls n=14*	*SymG n=11*	*AsymG n=14*
Adam`s Forward Bend Test, points	1,68±0,48	1,82±0,40	1,57±0,51	1,63±0,50	1,71±0,46
Abdominal muscle strength, reps/min	14,24±3,47	13,45±2,30	14,86±4,15	14,54±2,29	14,0±4,24
Back extensor strength, sec	86,48±29,14	85,91±29,48	86,93±29,98	88,18±28,65	85,14±30,52
New York Posture Rating scale, points	16,12±1,45	16,36±1,36	15,93±1,54	15,45±0,82	16,64±1,64*

Note: $p < 0.05$ indicates a statistically significant difference between the Symmetric Exercise Group (SymG) and the Asymmetric Exercise Group (AsymG)

There is a decrease in postural asymmetry and an increase in functional muscle endurance, as evidenced by an increase in abdominal muscle strength in boys (from 10 times per minute to 14) and girls (from 12 to 15 times per minute); and in groups of individual and group classes (from 11 to 14 times per minute). The strength of the back extensor muscles also increased. Among boys – from 64.55±28.41 to 85.91±29.48 sec; among girls – from 65.86±26.36 to 86.93±29.98 sec. In SimG there is an increase in indicators from 65.18±25.28 to 88.18±28.65 s, which indicates an increase of 23%, which demonstrates the best results among the groups; in AsymG – from 65.35±28.72 to 85.14±30.52, namely an increase of 19.79. The dynamics of changes is illustrated in Table 3.

Table 3. Pre-Post Changes (Δ) in Outcome Measures in Symmetric and Asymmetric Exercise Groups

Variables	*All n=25*	*Boys n=11*	*Girls n=14*	*p-value comparing boys and girls*	*SymG n=11*	*AsymG n=14*	*p-value comparing the groups*
Δ Adam`s Forward Bend Test, points	-0,28	-0,18	-0,36	0,35	-0,37	-0,21	0,43
Δ Abdominal muscle strength, reps/min	3,16	3,63	2,79	0,20	3,27	3,08	0,77
Δ Back extensor strength, sec	21,2	21,36	21,07	0,97	23	19,79	0,71
Δ New York Posture Rating scale, points	-1,68	-1,82	-1,57	0,20	-1,45	-1,86*	0,03

Note: $p < 0.05$ indicates a statistically significant difference between the Symmetric Exercise Group (SymG) and the Asymmetric Exercise Group (AsymG)

In general, it can be noted that the endurance of the abdominal muscles and back extensor strength significantly improved in all subjects, regardless of gender and physical therapy programme, which confirms the success of various forms of therapeutic exercises to stabilise the muscular corset and reduce postural asymmetry. Table 4 presents a detailed analysis of within-group differences between pre- and post-intervention outcomes.

The number of points for NYPR significantly decreased in SymG from 16.90±0.83 to 15.45±0.82, and in AsymG – from 18.50±1.65 to 16.64±1.65 points, which indicates a significant correction of posture. Participants of the AsymG showed better changes in indicators from 18.5±1.65 to 16.64±1.64, which is a decrease of 1.86%, which indicates significantly better results in posture symmetry compared to SymG.

Table 4. Comparison of pre- and post-intervention means in EG and CG using the paired t-test

Показники	*t-value*	*df*	*p-value*		*t-value*	*df*	*p-value*
	Symmetric Exercise Group				*Asymmetric Exercise Group*		
Adam`s Forward Bend Test, points	2,39	10	0,038		1,88	13	0,082
Abdominal muscle strength, reps/min	-7,64	10	0,000		-6,32	13	0,000
Back extensor strength, sec	-3,61	10	0,005		-3,55	13	0,004
New York Posture Rating scale, points	9,24	10	0,000		19,14	13	0,000

Note: t-value – t-statistic; df – degrees of freedom; p-value – significance level

At the beginning of the training, the Adam`s Forward Bend Test score of SymG was 2±0, and at the end of the training it was 1.63±0.50, which is a significant difference. At the same time, in AsymG it was 1.92±0.26 at the beginning and 1.71±0.46 at the end, and no significant difference was found.

DISCUSSION

At the beginning of the study, postural asymmetry was detected in all participants using the NYPR, with an average score of 17.80±1.55 points, which corresponds to a satisfactory level. The most frequent clinical manifestations of scoliosis were asymmetrical position of the head, shoulders, shoulder blades and waist triangles, which were detected in 100% of patients. Measurements of height and weight, followed by the calculation of BMI, indicate that the indicators of all subjects range from 20.04±1.43 (boys - 19.60±1.26, girls - 20.39±1.50), which corresponds to the upper limit of the norm in accordance with WHO recommendations [10].

The Risser test is used to assess the degree of growth of the pelvic bone structures in children and adolescents. Until the bone has completed active development, the deformity can progress rapidly. Only when the bone is fully formed and the growth zones are closed can we talk about some stabilisation of the scoliotic arch. The test scores range from 1 to 5, where 5 means full bone maturity. The Rieser test score in

84% of subjects was «2», which indicates ossification of 25-50%, and the Risser test scores of «3» and «4» were observed in 16% and indicated an approach to spinal stabilisation and ossification by 75%. In the study by Del Prete et al it was observed how scoliosis progresses, especially during the phase of active growth, and stabilisation of the scoliotic arch was observed at the end of active growth [11].

Shoulder imbalance or asymmetry is the most common manifestation of scoliosis. Despite the existence of many studies on this issue, a comprehensive review of risk factors and preventive measures has not yet been established. A noteworthy study by Nikouei et al describes that asymmetry of the upper arms is affected by the thorax, shoulder girdle and spine, and the assessment of the shoulder in scoliosis is based on three areas: the cervical spine, shoulder girdle and axilla [12]. Therefore, strengthening the abdominal muscles and back extensors to correct shoulder position and posture is absolutely essential. In addition, a study by Kocaman et al. also shows that two different types of therapeutic exercises can improve muscle function and reduce postural asymmetry [13].

Both physical therapy programs (featuring symmetric and asymmetric exercises) were effective for children with mild scoliosis. However, the individualized approach used in the asymmetric exercise program demonstrated more pronounced positive changes in functional and morphological parameters, despite the initially greater Cobb angle and postural impairments in this group. This suggests the relevance and importance of personalized rehabilitation planning for patients with more severe postural and spinal deformities.

It is well known that posture is an important functional component of health, and given the physiological characteristics of children, it should be understood that its development is affected by weakness and functional asymmetry of the corset muscles, reduced spinal mobility and muscle strength. Therefore, exercises are an integral component of scoliosis rehabilitation [14]. Wilczyński et al in their study described that therapeutic exercises play a very important role in reducing postural asymmetry, which can be formed from birth and during the period of active growth can become an impetus for the development of scoliotic deformity [15]. The study by Sarkisova N et al states that exercises in the side plank position asymmetrically strengthen the convex side of the iliolumbar muscle, lower back, oblique and transverse abdominal muscles. When these muscles are strengthened, the spine curves on the stronger side and reduces deformation [16].

Corrective therapeutic exercises aimed at spinal stabilization improve the functional state of the musculoskeletal system and enhance the strength of both deep and superficial muscles on both sides of the body. The study by Ma et al suggests that after performing the exercises, patients with scoliosis can maintain trunk balance, both at rest and during movement, using the strength of the peripheral spinal muscles [17]. In addition, the results of the study by Zhou et al indicate that therapeutic exercises have potential benefits for reducing the angle of rotation of the trunk, improving quality of life and reducing postural asymmetry [18].

Romano et al note that, compared to the complete absence of treatment, therapeutic exercises can reduce the progression of scoliosis and improve the quality of life. Also, exercises are more effective for mild scoliosis, which are aimed at improving posture and preventing an increase in Cobb's angle with subsequent surgery or corseting [19]. It should also be noted that with regular use of therapeutic exercises (at least 6 months), a slight decrease in Cobb's angle is observed in the early stages of scoliosis. The most commonly used type of asymmetric exercises is Schroth Therapy, which has repeatedly proven to be effective in reducing Cobb's angle and gives good results among the subjects [20]. Other studies have used conventional exercise programmes, which also showed good results in terms of visual posture assessment [21].

Thus, therapeutic exercises have many advantages. They include the absence of side effects, accessibility, overall improvement in quality of life, and aesthetic perception. Balance and coordination training, Pilates, and proprioceptive neuromuscular facilitation are widely used in the clinical practice of scoliosis treatment. This integrated therapeutic strategy is proving to be effective in relieving symptoms. However, achieving the most effective intervention strategy for scoliosis remains a challenge, and current guidelines do not provide guarantees of curvature reduction [22].

As scoliosis has a negative impact on daily life, including physical, social and psychological needs, a comprehensive approach is required that includes not only therapeutic exercises but also psychosocial interventions to improve psychosocial well-being. Psychosocial interventions are defined as interpersonal techniques aimed at improving well-being. Research on the effectiveness of these interventions is still limited, but the most promising is patient management after a rehabilitation programme [23].

Researchers' findings show that exercises have a positive effect not only in the rehabilitation of scoliosis but also in improving psychological well-being, while corseting can reduce patients' self-esteem and lead to anxiety and uncertainty [24].

The researchers compared the use of Schroth Therapy, SEAS, Dobomed, sideways shift exercises, active spinal self-correction and functional individual therapy to reduce Cobb's angle in scoliosis. A meta-analysis showed that SEAS was the most effective in reducing the curvature angle, followed by Schroth Therapy, with active self-correction having a greater impact on improving quality of life and demonstrating better short-term benefits than other interventions. Based on the current study results, it can be concluded that all techniques have a positive effect on improving physical and psychological qualities in scoliosis among children and adolescents [25].

Researchers believe that therapeutic exercises are the most alternative approach to the rehabilitation of mild scoliosis compared to corseting, which, when used for a long time without the ability to perform exercises, can lead to the development of a flat back and muscle weakness [20].

CONCLUSIONS

Following the completion of the two-week physical therapy programs in both individual and group settings, children with mild scoliosis, regardless of sex, demonstrated positive dynamics in abdominal and spinal extensor muscle strength, as well as in posture scores. While both physical therapy programs proved effective, greater postural deformities (as indicated by Cobb angle and NYPR scores) influenced the outcomes. The individualized approach with asymmetric exercises resulted in a significantly more favorable impact on postural symmetry, highlighting the relevance of personalized physical therapy program development for patients with more pronounced spinal and postural deformities.

PROSPECTS FOR FUTURE RESEARCH

Further studies should investigate the duration of therapeutic effects of physical therapy programs in children with mild scoliosis, develop a follow-up management algorithm after a two-week course, and explore strategies for educating parents to support increased physical activity in children.

AUTHOR CONTRIBUTIONS

Yezhova O.[A,C,D,E]; Lohynova V.[A,B,D]; Baryshok T. [A,D]

A – study design; B – data collection; C – statistical analysis; D – manuscript preparation; E – study administration.

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CONFLICT OF INTEREST

The authors have no conflict of interest to declare.

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During the preparation of this manuscript, the authors used ChatGPT (OpenAI) to assist with partial translation, English language editing, and proofreading. The AI tool was not used for data analysis, interpretation of results, or the development of scientific conclusions. All content was critically reviewed, revised, and approved by the authors, who assume full responsibility for the accuracy, integrity, and originality of the published work

ETHICAL CONSIDERATIONS

The parents of the children signed an informed voluntary consent for the treatment and rehabilitation of their children and permission to participate in the study and statistical processing of the results. The study protocol was reviewed and approved by the Bioethics Committee for Academic and Clinical Research of the Educational and Scientific Medical Institute of Sumy State University (Protocol No. 4/02, February 18, 2025).

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