Original article
https://doi.org/10.17816/2311-2905-17759

Comparison of Conservative Treatment Outcomes for Adolescent Idiopathic Scoliosis in Swimmers and Rhythmic Gymnastics Athletes

Marianna Ch. Semenistaia [1,3], Borislav Chongov [2,3], Anton A. Semenistyy [1,3]

[1] *Medical University of Sofia, Sofia, Bulgaria*
[2] *Vasil Levski National Sports Academy, Sofia, Bulgaria*
[3] *Prof. B. Boychev University Hospital for Orthopaedic, Sofia, Bulgaria*

Abstract

Background. The impact of regular sports activities and specific types of sports on the effectiveness of conservative treatment for adolescent idiopathic scoliosis (AIS) has not been sufficiently studied. Understanding this relationship is essential for personalizing programs of physiotherapeutic specific scoliosis exercises (PSSE) and preventing deformity progression.

The aim of the study — to compare the results of conservative therapy for adolescent idiopathic scoliosis among rhythmic gymnasts, swimmers, and patients not engaged in regular sports activities, as well as to evaluate the influence of sport type on changes in frontal and sagittal trunk balance parameters and flexibility.

Methods. A retrospective analysis was performed on 54 patients: 21 rhythmic gymnasts (Group 1), 11 swimmers (Group 2), and 22 non-athletic patients (Group 3, control). The groups were comparable in terms of key anthropometric and radiological parameters. All patients underwent PSSE according to the BSPTS Rigo method. TLSO bracing was used when indicated. Before and after treatment, the Cobb angle, thoracic kyphosis, lumbar lordosis, sagittal index, angle of trunk inclination (ATI), and flexibility (sit-and-reach test) were assessed.

Results. Significant intergroup differences were found only for the Cobb angle ($H = 9.366$; $p = 0.007$) during treatment. Post-hoc analysis revealed that gymnasts showed a statistically significantly greater reduction in Cobb angle compared with the control group ($p < 0.0167$). Differences between the control group and swimmers, as well as between gymnasts and swimmers, did not reach statistical significance after adjustment. No significant intergroup differences were found for other parameters (thoracic kyphosis, lumbar lordosis, sagittal index, flexibility, body mass, and height). Intragroup analysis demonstrated a statistically significant decrease in Cobb angle and ATI among gymnasts, and improved flexibility in both gymnasts and the control group. Deformity progression greater than 5° occurred less frequently in athletes (3.1%) than in non-athletic patients (27.3%; $p = 0.0144$).

Conclusion. Conservative treatment based on physiotherapeutic specific scoliosis exercises is effective in all patients with adolescent idiopathic scoliosis. Rhythmic gymnasts demonstrated a more pronounced correction of frontal plane deformity and a greater reduction in trunk inclination compared with non-athletic patients. Swimming did not show advantages for correction of deformities in either the frontal (Cobb angle) or sagittal (lordosis, kyphosis) planes.

Keywords: adolescent idiopathic scoliosis; physiotherapy; bracing; PSSE (BSPTS Rigo); rhythmic gymnastics; swimming; Cobb angle.

Cite as: Semenistaia M.Ch., Chongov B., Semenistyy A.A. Comparison of Conservative Treatment Outcomes for Adolescent Idiopathic Scoliosis in Swimmers and Rhythmic Gymnastics Athletes. *Traumatology and Orthopedics of Russia*. 2025;31(4):111-119. (In Russian). https://doi.org/10.17816/2311-2905-17759.

✉ *Anton A. Semenistyy*; e-mail: an.semenistyy@gmail.com

Submitted: 27.08.2025. Accepted: 20.10.2025. Published online: 10.11.2025.

Научная статья
УДК 616.711-007.55-08-039.73-053.7
https://doi.org/10.17816/2311-2905-17759

Сравнение результатов консервативного лечения юношеского идиопатического сколиоза у пловцов и спортсменов художественной гимнастики

М.Ч. Семенистая [1,3], Б. Чонгов [2,3], А.А. Семенистый [1,3]

[1] Медицинский университет Софии, г. София, Болгария
[2] Национальная спортивная академия Васила Левски, г. София, Болгария
[3] Университетская специализированная ортопедическая больница им. проф. Б. Бойчева, г. София, Болгария

Реферат

Актуальность. Влияние регулярных занятий спортом и его вида на эффективность консервативного лечения юношеского идиопатического сколиоза (ЮИС) изучено недостаточно. Определение этой корреляции важно для персонализации программ специфических упражнений (PSSE) и профилактики прогрессирования деформации.

Цель исследования — сравнить результаты консервативной терапии юношеского идиопатического сколиоза у спортсменов художественной гимнастики, пловцов и пациентов, не занимающихся регулярно спортом, а также оценить влияние вида спорта на изменение фронтальных и сагиттальных параметров баланса туловища и гибкости.

Материал и методы. Проведен ретроспективный анализ лечения 54 пациентов: 21 гимнастки (группа 1), 11 пловцов (группа 2) и 22 пациентов, не занимающихся регулярно спортом, (группа 3, контрольная). Группы были сопоставимы по основным антропометрическим и рентгенологическим показателям. Всем пациентам проводили PSSE по BSPTS Rigo; при наличии показаний применялся корсет TLSO. До и после лечения оценивали угол Кобба, грудной кифоз, поясничный лордоз, сагиттальный индекс, угол наклона туловища (ATI) и гибкость (sit-and-reach тест).

Результаты. Значимые межгрупповые различия выявлены только в величине угла Кобба ($H = 9{,}366$; $p = 0{,}007$) в ходе лечения. Апостериорный анализ показал, что у гимнасток снижение величины угла Кобба было статистически значимо больше по сравнению с контрольной группой ($p < 0{,}0167$). Различия между контрольной группой и пловцами, а также между гимнастками и пловцами не достигли статистической значимости после поправки. Для остальных параметров (грудной кифоз, поясничный лордоз, сагиттальный индекс, гибкость, масса и рост) межгрупповых различий не выявлено. Внутригрупповой анализ показал статистически значимое уменьшение угла Кобба и ATI у гимнасток, а также улучшение гибкости у гимнасток и в контрольной группе. Прогрессирование деформации более 5° у спортсменов наблюдалось реже (3,1%), чем у пациентов, не занимающихся регулярно спортом, (27,3%; $p = 0{,}0144$).

Заключение. Консервативное лечение на основе PSSE эффективно у всех пациентов с юношеским идиопатическим сколиозом. У гимнасток отмечены более выраженная коррекция деформации во фронтальной плоскости и снижение угла наклона туловища по сравнению с пациентами, не занимающимися регулярно спортом. Не выявлено преимуществ плавания для коррекции деформации во фронтальной (угол Кобба) и сагиттальной плоскостях (лордоз, кифоз).

Ключевые слова: юношеский идиопатический сколиоз; физиотерапия; корсетотерапия, PSSE (BSPTS Rigo); художественная гимнастика; плавание; угол Кобба.

Для цитирования: Семенистая М.Ч., Чонгов Б., Семенистый А.А. Сравнение результатов консервативного лечения юношеского идиопатического сколиоза у пловцов и спортсменов художественной гимнастики. *Травматология и ортопедия России*. 2025;31(4):111-119. https://doi.org/10.17816/2311-2905-17759.

Семенистый Антон Алексеевич; e-mail: an.semenistyy@gmail.com

Рукопись получена: 27.08.2025. Рукопись одобрена: 20.10.2025. Статья опубликована онлайн: 10.11.2025.

INTRODUCTION

Adolescent idiopathic scoliosis (AIS) occurs in 1-3% of adolescents and represents a three-dimensional deformity of the spine characterized by a lateral curvature greater than 10° in the frontal plane [1]. The etiological factors of AIS have not been fully established. However, genetic predisposition, specific features of musculoskeletal growth, hormonal influences, and mechanical loading are believed to play a role in its development [2]. The diagnosis is typically made between the ages of 10 and 18, and the disease tends to progress during the periods of rapid growth, leading to significant cosmetic and functional impairments [2].

The role of physical activity in the development and progression of AIS remains a matter of debate. Different types of sports have varying effects on the spine and the musculoskeletal system [3]. Rhythmic gymnastics is associated with high flexibility demands and asymmetric, extreme ranges of motion, which may increase the mechanical load on the spine and, according to several authors, contribute to the progression of scoliotic deformity in adolescents [4, 5, 6, 7].

In 1996, P. Tanchev et al. performed a screening examination of 4.800 schoolgirls aged 11-14 years and identified scoliosis in 1.1% of them [7]. In 2000, the same authors performed a similar study involving 100 athletes actively engaged in rhythmic gymnastics and found that scoliosis occurred ten times more frequently (12%). The scoliotic deformities were mild to moderate in severity and were associated with delayed menarche, generalized joint hypermobility, and repetitive asymmetric spinal loading during growth, which is typical for this type of sport [8].

Swimming, on the other hand, has traditionally been regarded as a balanced form of physical activity that promotes uniform muscular development, improves posture, and reduces the risk of spinal deformities [3, 5]. However, recent studies show that regular swimming training does not always prevent the development or progression of the disease and, according to some authors, may even increase the risk of AIS [9, 10].

For curvatures less than 45°, conservative treatment is indicated, which includes an individualized program of scoliosis-specific corrective exercises (Physiotherapy Scoliosis Specific Exercises, PSSE). For curvatures greater than 25°, orthotic management using thoracolumbosacral braces is recommended [11, 12, 13, 14]. The effectiveness of PSSE and brace therapy has been confirmed by numerous studies. However, their outcomes in athletes who are regularly exposed to sport-specific physical loads remain insufficiently studied [14, 15, 16, 17, 18].

The 2016 SOSORT guidelines emphasize that sports activities should not be prescribed as an independent treatment method for idiopathic scoliosis, as their goals differ from those of PSSE, which specifically targets the correction of deformity, functional impairment, and postural control [5]. Nevertheless, patients are encouraged to maintain regular physical activity, as participation in sports generally does not affect the occurrence or severity of scoliosis and provides psychophysical benefits. Correlations have been identified for certain sports: swimming — with trunk asymmetries and hyperkyphosis, although without proven causality; tennis — with no detected association with spinal deformities; gymnastics and ballet — with a higher prevalence of scoliosis, likely related to hyperlaxity and delayed menarche. During brace treatment, aerobic training may help maintain respiratory function [18, 19, 20].

The analysis of treatment outcomes in athletes with AIS engaged in different sports disciplines allows for assessing whether the nature of athletic loading influences the effectiveness of conservative therapy. Comparing rhythmic gymnastics and swimming in this context is of particular interest, as these sports differ significantly in movement biomechanics, load symmetry, and training regimen.

The aim of the study – to compare the results of conservative therapy for adolescent idiopathic scoliosis among rhythmic gymnasts, swimmers, and patients not engaged in regular sports activities, as well as to evaluate the influence of sport type on changes in frontal and sagittal trunk balance parameters and flexibility.

METHODS

Study design

The study design was retrospective and cohort-based.

Conservative treatment outcomes of AIS were evaluated in 54 patients: professional rhythmic gymnasts (Group 1), professional swimmers

(Group 2), and individuals not engaged in professional sports (Group 3, control group). Treatment was carried out between 2015 and 2022. The end of treatment was defined as the attainment of skeletal maturity (Risser stage 5). Follow-up assessments were conducted at two fixed time points: before treatment (baseline examination) and upon reaching skeletal maturity (final examination). The mean follow-up duration was 44.3 months (range: 12-65 months).

Inclusion criteria: diagnosis of AIS with a Cobb angle of 10-45°; age 10-15 years at treatment initiation; Risser stage 0-3; availability of at least two spinal X-rays (including the baseline one).

Exclusion criteria: secondary scoliosis; refusal of participation by the patient's legal representative; non-compliance with the prescribed rehabilitation program.

Group 1 included 21 patients (all female), Group 2 — 11 patients (7 females and 4 males), and Group 3 — 22 patients (17 females and 5 males). The groups were homogeneous in terms of age, changes in anthropometric parameters over the observation period (height and body weight), sagittal index, and severity of spinal curvature (Cobb angle, kyphosis, and lordosis). However, they differed significantly in baseline height, body weight, flexibility (assessed using the sit-and-reach test) [20], and in the number and duration of training sessions. The gymnasts demonstrated substantially higher flexibility compared to participants in Groups 2 and 3.

Treatment protocol

All patients followed a standardized program of physiotherapy scoliosis-specific exercises (PSSE) based on the BSPTS Rigo concept [21]. The program included one individual session with a certified physiotherapist per month (90 minutes) and home exercises performed five times per week for 20 minutes. The exercises were aimed at posture correction, breathing training, and activation and integration of postural muscle chains.

A rigid thoracolumbosacral orthosis (TLSO) was prescribed in 25 cases (8 gymnasts, 6 swimmers, and 11 patients in the control group). Indications for bracing were determined according to the Scoliosis Research Society (SRS) criteria, which include: a Cobb angle of 25-40° with documented curve progression, or a Cobb angle of 20-25° in patients at high risk of progression (Risser 0-2) [22].

When prescribed, brace wear time ranged from 18 to 23 hours per day. The orthotic devices used were designed in accordance with the principles of the Rigo-Chêneau system and the BSPTS methodology [21].

Evaluation of treatment outcomes

The following clinical and radiological parameters were used to assess treatment outcomes: 1) Cobb angle (spinal X-ray in the AP view) and sagittal index (in mm); 2) thoracic kyphosis and lumbar lordosis angles (measured using an inclinometer); 3) angle of trunk inclination (ATI), determined with a scoliometer; 4) flexibility, measured using the sit-and-reach test; 5) anthropometric data (height and body weight), recorded at baseline and final examinations; 6) proportion of cases showing scoliosis progression greater than 5° (considered as failure of conservative treatment).

Statistical analysis

Descriptive statistics were used to summarize demographic and clinical data. Quantitative variables with a normal distribution were presented as mean ± standard deviation (M±SD), while those with a non-normal distribution were presented as median, interquartile range, and extreme values (Me [Q_1; Q_3] (min-max)).

The normality of distribution was assessed using the Shapiro-Wilk test. For normally distributed variables, comparisons between independent groups were performed using one-way analysis of variance (ANOVA) with Tukey post-hoc test. Paired samples were analyzed using the paired Student's t-test. For non-normally distributed variables, nonparametric tests were applied: comparisons among three independent groups were performed using the Kruskal-Wallis test with exact p-values calculated via the Monte Carlo method. When required, post-hoc analysis was conducted using the Mann-Whitney test with Bonferroni correction. Within-group differences (before and after treatment) were analyzed using the Wilcoxon signed-rank test.

For comparative analysis of proportions, Pearson's χ^2 test was used. In pairwise comparisons, Fisher's exact two-tailed test was applied. Differences were considered statistically significant at $p < 0.05$. Statistical analysis was performed using SPSS Statistics v.26.0 (IBM, USA).

RESULTS

The Shapiro-Wilk test for normality showed a normal distribution for most variables, including age, height (before treatment), flexibility (sit-and-reach test), and scoliosis severity parameters (Cobb angle, kyphosis, lordosis, and sagittal index). Deviations from the normal distribution were found for body weight (both at baseline and in its change over the observation period) and for change in height during follow-up. The assessment of group comparability for these characteristics is presented in Table 1.

The Shapiro-Wilk test also demonstrated a normal distribution for all evaluated parameters except for the change in Cobb angle following treatment.

In Group 1, a statistically significant reduction in Cobb angle was observed. In Group 2, the Cobb angle also decreased, though this change was not statistically significant. In Group 3, a slight, statistically non-significant increase in Cobb angle was recorded.

Patients in Groups 1 and 2 also demonstrated a statistically significant improvement in the ATI measured with a scoliometer before and after treatment, while in Group 3, the change in this parameter was not statistically significant. No statistically significant changes were observed in sagittal index, thoracic kyphosis, or lumbar lordosis across all three groups.

Improvement in flexibility (sit-and-reach test) was noted among patients in all three groups (Table 2).

Before treatment, no statistically significant differences were found between the groups in the main parameters — Cobb angle, kyphosis, lordosis, sagittal index, and ATI ($p > 0.05$). The only exception was the flexibility measure (sit-and-reach test): gymnasts demonstrated significantly higher baseline values compared with swimmers and patients not engaged in regular sports (ANOVA $p < 0.001$; Tukey post-hoc test for both pairs $p < 0.001$).

After treatment, statistically significant differences in Cobb angle were observed between Groups 1 and 3 ($p = 0.008$), while the differences between Groups 1 and 2 and between Groups 2 and 3 did not reach statistical significance. Differences in thoracic kyphosis were also identified: patients in Group 2 showed higher values compared to Group 1 ($p = 0.027$). No intergroup differences were found in lumbar

Table 1

Assessment of group comparability at baseline

Parameter	Group 1 (n = 21)	Group 2 (n = 11)	Group 3 (n = 22)	p
Criteria for normally distributed data (ANOVA; t-test), M±SD				
Age, years	12.13±1.70	12.50±1.30	12.64±1.20	0.468
Height, cm	149.1±11.6	159.3±11.1	158.5±9.7	0.024
Cobb angle, deg.	22.3±8.3	26.6±12.5	25.3±7.0	0.363
Thoracic kyphosis, deg.	20.8±11.8	30.5±18.9	24.5±10.2	0.143
Lumbar lordosis, deg.	29.9±10.2	30.0±11.9	29.0±6.8	0.939
Sagittal index, mm	30.7±31.0	54.5±44.4	39.3±28.3	0.164
Sit-and-reach test, cm	17.5±6.7	-1.1±13.8	-0.1±8.9	< 0.001
Number of training sessions per week	5.4±0.6	4.8±0.7	–	0.027
Duration of training sessions, h.	4.8±1.4	1.5±0.6	–	< 0.001
Criteria for non-normally distributed data (the Kruskal-Wallis test with exact p-values calculated via the Monte Carlo method), Me [Q_1; Q_3] (min-max)				
Change in height during follow-up	6.4 [5.0; 10.6] (0.4-28.6)	6.1 [3.3; 13.1] (2.0-27.9)	7.3 [3.6; 10.2] (-4.2-18.7)	0.981
Weight, kg	38.0 [31.5; 44.6] (20.0-53.1)	47.9 [37.8; 51.3] (33.4-66.3)	46.1 [39.0; 54.4] (34.4-75.2)	< 0.001
Change in weight during follow-up	7.2 [4.0; 12.0] (0.2-25.1)	6.3 [3.6; 12.7] (0.0-20.4)	7.9 [5.3; 11.4] (-5.0-16.2)	0.825

lordosis, sagittal index, or ATI. As before treatment, patients in Group 1 demonstrated significantly higher flexibility than those in Groups 2 ($p < 0.001$) and 3 ($p < 0.001$).

The analysis of mean changes in parameters after treatment showed that the change in ATI was statistically significant only between Groups 1 and 3: -6.57±6.05° vs +0.45±8.19° ($p = 0.009$) and -2.81±2.87 vs -0.23±3.54 ($p = 0.023$), respectively. No intergroup differences were found in the mean changes of kyphosis, lordosis, sagittal index, or flexibility ($p > 0.05$) (Table 3).

According to the nonparametric Kruskal-Wallis analysis, significant differences between the groups were observed in the change of Cobb angle during treatment ($H = 9.366$; $p = 0.007$). Post-hoc analysis using the Mann-Whitney test with Bonferroni correction revealed a statistically significant difference in the change of Cobb angle between Groups 1 and 3 ($p < 0.0167$). Differences between Groups 2 and 3 and between Groups 1

Table 2

Within-group analysis of conservative scoliosis treatment outcomes (paired t-test)

Parameter		Group 1 (n = 21)		Group 2 (n = 11)		Group 3 (n = 22)	
		M±SD	p	M±SD	p	M±SD	p
Cobb angle, deg.	before treatment	22.33±8.31	< 0.001	26.60±12.57	0.284	25.36±7.00	0.797
	after treatment	15.76±7.94		23.60±18.14		25.82±7.97	
Thoracic kyphosis, deg.	before treatment	20.86±11.80	0.873	30.55±18.98	0.906	24.59±10.22	0.207
	after treatment	20.57±9.98		31.09±12.68		27.05±10.07	
Lumbar lordosis, deg.	before treatment	29.95±10.21	0.705	30.00±11.86	0.421	29.05±6.86	0.540
	after treatment	29.05±6.89		32.36±9.16		29.95±6.34	
Sagittal index, mm	before treatment	30.71±31.04	0.213	54.55±44.47	0.884	39.32±28.30	0.762
	after treatment	38.57±17.40		55.91±29.22		40.91±25.76	
ATI, deg.	before treatment	8.43±4.08	< 0.001	9.09±6.02	0.005	9.23±4.06	0.767
	after treatment	5.62±4.05		6.55±5.93		9.00±4.49	
Sit-and-reach test, cm	before treatment	17.52±6.69	0.008	-1.09±13.8	0.017	-0.11±8.90	< 0.001
	after treatment	21.24±5.38		4.00±15.06		5.50±8.80	

Table 3

Between-group analysis of conservative scoliosis treatment outcomes (one-way ANOVA with Tukey post-hoc test)

Parameter		Group 1 (n = 21)	Group 2 (n = 11)	Group 3 (n = 22)	ANOVA p	Tukey p Gr. 1–Gr. 2	Tukey p Gr. 1–Gr. 3	Tukey p Gr. 2–Gr. 3
Cobb angle, deg.	before treatment	22.33±8.31	26.60±12.57	25.36 ±7.00	0.363	0.419	0.498	0.927
	after treatment	15.76±7.94	23.60±18.14	25.82 ±7.97	0.009	0.140	0.008	0.846
Thoracic kyphosis, deg.	before treatment	20.86±11.80	30.55±18.98	24.59±10.22	0.143	0.121	0.616	0.434
	after treatment	20.57 ±9.98	31.09±12.68	27.05±10.07	0.024	0.027	0.122	0.559
Change of thoracic kyphosis		-0,29±8,06	0.55±14.98	2.45±8.84	0.665	0.973	0.648	0.865
Lumbar lordosis, deg.	before treatment	29.95±10.21	30.00±11.86	29.05±6.86	0.939	1.000	0.946	0.959
	after treatment	29.05±6.89	32.36±9.16	29.95±6.34	0.465	0.435	0.910	0.637

End of Table 3

Between-group analysis of conservative scoliosis treatment outcomes (one-way ANOVA with Tukey post-hoc test)

Parameter		Group 1 (n = 21)	Group 2 (n = 11)	Group 3 (n = 22)	ANOVA p	Tukey p Gr. 1–Gr. 2	Tukey p Gr. 1–Gr. 3	Tukey p Gr. 2–Gr. 3
Change of lumbar lordosis		-0,90±10,80	2.36±9.34	0.91±6.85	0.605	0.600	0.790	0.901
Sagittal index, mm	before treatment	30.71±31.04	54.55±44.47	39.32±28.30	0.164	0.139	0.672	0.432
	after treatment	38.57±17.40	55.91±29.22	40.91±25.76	0.134	0.130	0.944	0.209
Change in sagittal index		7.86±28.00	1.36±30.26	1.59±24.27	0.704	0.795	0.729	1.000
ATI, deg.	before treatment	8.43±4.18	9.09±6.32	9.23±4.06	0.842	0.922	0.839	0.997
	after treatment	5.62±4.15	6.55±6.22	9.00±4.49	0.068	0.861	0.061	0.350
Change in ATI		-2.81±2.87	-2.55±2.38	-0.23±3.54	0.019	0.971	0.022	0.114
Sit-and-reach test, cm	before treatment	17.52±6.86	1.09±14.48	-0.11±8.90	<0.001	<0.001	<0.001	0.959
	after treatment	21.24±5.51	4.00 ±15.79	5.50±8.80	<0.001	<0.001	<0.001	0.907
Change in flexibility		3.71±5.75	5.09 ±5.94	5.61±6.58	0.590	0.820	0.572	0.971

and 2 did not reach statistical significance after correction (p > 0.0167) (Table 4).

Furthermore, differences between groups were found in the proportion of cases with curve progression. Progression greater than 5° was observed in only one (3.1%) athlete — an 18° increase (from 44 to 62°) — and in six (27.3%) patients from the non-athlete group. This difference was statistically significant (p = 0.014).

Table 4

Comparison of groups by the magnitude of Cobb angle change during treatment (post-hoc Mann-Whitney test with Bonferroni correction)

Comparison	U	Z	p (uncorrected)	p (Bonferroni)	r (effect size)
Group 1 vs Group 3	370	3.38	< 0.001	0.0023	0.52 (medium to large)
Group 2 vs Group 3	164	1.64	0.105	0.314	0.29 (small to medium)
Group 1 vs Group 2	109	-0.26	0.812	1.000	0.05 (negligible)

DISCUSSION

The results of the present study demonstrated that the type of athletic activity influences the effectiveness of conservative therapy for AIS. Under a standardized PSSE (BSPTS Rigo) protocol and, when indicated, bracing, rhythmic gymnasts showed a marked reduction in the ATI and greater correction of the Cobb angle compared with patients not engaged in regular sports. Among swimmers, the decrease in Cobb angle did not reach statistical significance. However, their final thoracic kyphosis values were higher than those of the gymnasts. The proportion of curve progressions greater than 5° was lower among athletes overall. These findings are consistent with current concepts of conservative scoliosis management and suggest that the biomechanical profile of training — asymmetrical and coordinative in rhythmic gymnastics versus predominantly symmetrical and cyclical in swimming — may interact differently with the mechanisms of PSSE and bracing [18, 20, 23].

Our observations align with contemporary evidence on the benefits of early, individualized, scoliosis-specific exercises (PSSE) [19, 20]. According to the literature, in adolescents with curves below 25°, PSSE can stabilize or reduce the deformity, while bracing combined with

PSSE is effective for more severe curvatures [11, 12, 13]. The more pronounced positive dynamics observed in rhythmic gymnasts are likely related to superior postural control and trunk coordination, inherent to the specific demands of this sport. The symmetrical nature of swimming loads exerts a lesser influence on the three-dimensional, including rotational and torsional, components of spinal deformity, which may explain the less pronounced frontal correction despite adherence to a comparable PSSE protocol.

Our findings are consistent with the observations of G. Bielec et al., who reported that standard school swimming lessons (45 minutes per week over 2 years; ~600 m per session) have little effect on most postural defects in adolescents and are only slightly associated with scoliosis regression compared with controls, without significant changes in growth or BMI. The authors emphasized the need for individualized training programs rather than "general" swimming. In our study, under a standardized protocol (PSSE (BSPTS Rigo) ± bracing), rhythmic gymnastics was associated with greater frontal correction (lower final Cobb angle and greater reduction; more pronounced decrease in ATI) compared with no regular sports participation. Among swimmers, the decrease in Cobb angle did not reach statistical significance, and final thoracic kyphosis values were higher than in gymnasts. These differences support Bielec et al.'s conclusion that symmetrical, cyclic loading in water alone does not replace a personalized, three-dimensional corrective program and, if performed with improper technique (e.g., unilateral breathing in freestyle), may contribute to asymmetry. Therefore, for swimmer athletes, PSSE should be complemented with targeted aquatic modules that modify stroke patterns and breathing under physiotherapist supervision [18].

Study limitations

The limitations of this study include its retrospective design, unequal group sizes (particularly the swimmers), incomplete control over the dose and adherence to both sports activity and PSSE/bracing, as well as the use of inclinometer and scoliometer measurements for some metrics instead of biplanar 3D assessment. Nevertheless, the use of a standardized treatment protocol and comparability of baseline radiological parameters enhance the internal validity of the study.

CONCLUSION

The application of scoliosis-specific exercises according to the PSSE (BSPTS Rigo) concept, combined with appropriate bracing, achieves comparable clinical effectiveness regardless of the type of sport practiced. Comparison between rhythmic gymnastics and swimming showed similar outcomes in key corrective parameters when the PSSE protocol was followed. Potential differences were limited to secondary parameters and did not alter the overall trend. Therefore, training loads should be individualized according to age, growth stage, and risk of progression, and supplemented with defect-oriented PSSE elements.

DISCLAIMERS

Author contribution

Semenistaia M.Ch. — data acquisition, analysis and interpretation, literature search, drafting the manuscript.

Chongov B. — study concept and design, data acquisition, analysis and interpretation, editing the manuscript.

Semenistyy A.A. — study concept and design, data analysis, statistical data processing, editing the manuscript.

All authors have read and approved the final version of the manuscript of the article. All authors agree to bear responsibility for all aspects of the study to ensure proper consideration and resolution of all possible issues related to the correctness and reliability of any part of the work.

Funding source. Young Scientists Support Program, Medical University of Sofia.

Disclosure competing interests. The authors declare that they have no competing interests.

Ethics approval. The study was approved by the local ethics committee of Prof. B. Boychev University Hospital for Orthopaedic, protocol No EK-3/24, 23.03.2024.

Consent for publication. Written consent was obtained from the legal representatives of children to participate in the study and publish the results.

Use of artificial intelligence. No generative artificial intelligence technologies were used in the preparation of this manuscript.

REFERENCES

1. Kuznia A.L., Hernandez A.K., Lee L.U. Adolescent Idiopathic Scoliosis: Common Questions and Answers. *Am Fam Physician.* 2020;101(1):19-23.
2. Kikanloo S.R., Tarpada S.P., Cho W. Etiology of Adolescent Idiopathic Scoliosis: A Literature Review. *Asian Spine J.* 2019;13(3):519-526. doi: 10.31616/asj.2018.0096.
3. Mousavi L., Seidi F., Minoonejad H., Nikouei F. Prevalence of idiopathic scoliosis in athletes: a systematic review and meta-analysis. *BMJ Open Sport Exerc Med.* 2022;8(3):e001312. doi: 10.1136/bmjsem-2022-001312.
4. Scaturro D., Costantino C., Terrana P., Vitagliani F., Falco V., Cuntrera D. et al. Risk Factors, Lifestyle and Prevention among Adolescents with Idiopathic Juvenile Scoliosis: A Cross Sectional Study in Eleven First-Grade Secondary Schools of Palermo Province, Italy. *Int J Environ Res Public Health.* 2021;18(23):12335. doi: 10.3390/ijerph182312335.
5. Negrini S., Donzelli S., Aulisa A.G., Czaprowski D., Schreiber S., de Mauroy J.C. et al. 2016 SOSORT guidelines: Orthopedic and rehabilitation treatment of idiopathic scoliosis during growth. *Scoliosis Spinal Disord.* 2018;13:3. doi: 10.1186/s13013-017-0145-8.
6. Gubskaya K.D., Lunina N.V. Risk factors for the development and progression of scoliosis in adolescent athletes in rhythmic gymnastics: a literature review. *Russian Journal of Sports Science: Medicine, Physiology, Training.* 2022;3(3). (In Russian). doi: 10.51871/2782-6570_2022_01_03_4.
7. Tanchev P., Dikov D., Dzherov A., Parushev A., Zaharieva L., Todorov N. et al. School screening for scoliosis in Sofia: An analysis of screening results of 4800 students. *Ortop Trauma.* 1996;33(2):69-73.
8. Tanchev P.I., Dzherov A.D., Parushev A.D., Dikov D.M., Todorov M.B. Scoliosis in rhythmic gymnasts. *Spine (Phila Pa 1976).* 2000;25(11):1367-1372. doi: 10.1097/00007632-200006010-00008.
9. Gonen Aydin C., Oner A., Hekim H.H., Arslan A.S., Oztas D., Akman Y.E. The prevalence of scoliosis in adolescent swimmers and the effect of swimming on adolescent idiopathic scoliosis. *Turk J Sports Med.* 2020;55(3):200-206. doi: 10.5152/tjsm.2020.176.
10. Zaina F., Donzelli S., Lusini M., Minnella S., Negrini S. Swimming and spinal deformities: a cross-sectional study. *J Pediatr.* 2015;166(1):163-167. doi: 10.1016/j.jpeds.2014.09.024.
11. Tsykunov M.B. Medical rehabilitation with scoliotic deformations. *Bulletin of Rehabilitation Medicine.* 2018;17(4): 75-91. (In Russian).
12. Shavyrin I.A., Levkov V.Yu., Lobov A.N. The use of corrective chenot corset in the treatment of idiopathic scoliosis in children and adolescents. *Russian Medicine.* 2020;26(1):10-15. (In Russian). doi: 10.18821/0869-2106-2020-26-1-10-15.
13. Nikolaev V., Baranovskaia I., Andrievskaia A. Use of a functional correcting brace in treatment of patients with idiopathic scoliosis. *Genij Ortopedii.* 2016;(1):44-47. (In Russian). doi: 10.18019/1028-4427-2016-1-44-47.
14. Seleviciene V., Cesnaviciute A., Strukcinskiene B., Marcinowicz L., Strazdiene N., Genowska A. Physiotherapeutic Scoliosis-Specific Exercise Methodologies Used for Conservative Treatment of Adolescent Idiopathic Scoliosis, and Their Effectiveness: An Extended Literature Review of Current Research and Practice. *Int J Environ Res Public Health.* 2022;19(15):9240. doi: 10.3390/ijerph19159240.
15. Kaelin A.J. Adolescent idiopathic scoliosis: indications for bracing and conservative treatments. *Ann Transl Med.* 2020;8(2):28. doi: 10.21037/atm.2019.09.69.
16. Karavidas N., Tzatzaliaris D. Brace and Physiotherapeutic Scoliosis Specific Exercises (PSSE) for Adolescent Idiopathic Scoliosis (AIS) treatment: a prospective study following Scoliosis Research Society (SRS) criteria. *Arch Physiother.* 2022;12(1):22. doi: 10.1186/s40945-022-00150-5.
17. Negrini A., Donzelli S., Vanossi M., Poggio M., Cordani C., Zaina F. et al. Sports participation reduces the progression of idiopathic scoliosis and the need for bracing. An observational study of 511 adolescents with Risser 0-2 maturation stage. *Eur J Phys Rehabil Med.* 2023; 59(2):222-227. doi: 10.23736/S1973-9087.23.07489-0.
18. Bielec G., Peczak-Graczyk A., Waade B. Do swimming exercises induce anthropometric changes in adolescents? *Issues Compr Pediatr Nurs.* 2013;36(1-2):37-47. doi: 10.3109/01460862.2013.777818.
19. Muccio M., Atun-Einy O., Kafri M., Kaplan S.L. Bridging Motor Learning Principles with Physiotherapy Specific Scoliosis Exercises: a Perspective Article. *Phys Occup Ther Pediatr.* 2023;43(6):741-758. doi: 10.1080/01942638.2023.2186198.
20. Ayala F., Sainz de Baranda P., De Ste Croix M., Santonja F. Reproducibility and criterion-related validity of the sit and reach test and toe touch test for estimating hamstring flexibility in recreationally active young adults. *Phys Ther Sport.* 2012;13(4):219-226. doi: 10.1016/j.ptsp.2011.11.001.
21. Berdishevsky H., Lebel V.A., Bettany-Saltikov J., Rigo M., Lebel A., Hennes A. et al. Physiotherapy scoliosis-specific exercises – a comprehensive review of seven major schools. *Scoliosis Spinal Disord.* 2016;11:20. doi: 10.1186/s13013-016-0076-9.
22. Richards B.S., Bernstein R.M., D'Amato C.R., Thompson G.H. Standardization of criteria for adolescent idiopathic scoliosis brace studies: SRS Committee on Bracing and Nonoperative Management. *Spine (Phila Pa 1976).* 2005;30(18):2068-2075. doi: 10.1097/01.brs.0000178819.90239.d0.
23. Levkov V.Yu., Panyukov M.V., Andronova L.B., Lobov A.N., Tsoi S.V., Levkova T.V. et al. Conscious correction of scoliosis and posture disorders: scientific and practical guidance. Moscow: Sport; 2020. 144 p. (In Russian).

Authors' information

✉ *Anton A. Semenistyy* — Cand. Sci. (Med.)
Address: 15, Boulevard Acad. Ivan Geshov, Sofia, 1431, Bulgaria
https://orcid.org/0000-0002-5412-6202
eLibrary SPIN: 9574-7495
e-mail: an.semenistyy@gmail.com

Marianna Ch. Semenistaia
https://orcid.org/0000-0002-1724-4760
eLibrary SPIN: 9357-3700
e-mail: marianna.semenistaia@yahoo.com

Borislav Chongov — Cand. Sci. (Med.)
https://orcid.org/0000-0002-4857-8624
e-mail: borislav.chongov@nsa.bg