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Effects of Specific Exercise Therapy on Adolescent Patients With Idiopathic Scoliosis

A Prospective Controlled Cohort Study

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Study Design. A prospective controlled cohort study.

Objective. The aim of this study was to explore the interventional effect of exercise therapy on idiopathic scoliosis (IS) and identify an optimal intervention window.

Summary of Background Data. Early conservative treatment is helpful for IS. In addition to bracing, current evidence suggests that exercise can play an important role.

Methods. We included 99 patients with IS who were treated at the Guangdong Xinmiao Scoliosis Center from August 2013 to September 2017. The inclusion criteria were: new IS diagnosis, Cobb angle 10° to 25°, Risser 0 to 3 grade, only treated with the Xinmiao treatment system (XTS; >3 days/week, >1 h/day), and follow-up >1 year. Patients were divided into three age groups: A, <10 years (n = 29); B, 10 to 12 years (n = 24); and C, 13 to 15 years (n = 46). The percentages of curve improvement (Cobb angle decrease ≥5°), stability (Cobb angle change × ±5°), and progression (Cobb angle increase ≥5°) were compared.

Results. The groups showed significant differences for major curve correction, Risser sign, first referral, and final follow-up of the main curve (all $P < 0.05$). The major curve in group A decreased significantly by 6.8° (44% correction), compared to 3.1° (18% correction) and 1.5° (9% correction) in groups B and C, respectively. In group A, 69.0% (20/29) had curve improvement, 27.6% (8/29) stabilized and 3.4% (1/29) progressed. In group B, 45.8% (11/24) improved, 50% (12/24) stabilized, and 4.2% (1/24) progressed. In group C, 26.1% (12/46) improved, 63.0% (29/46) stabilized, and 10.9% (5/46) progressed. There was also a significant difference in final Risser grade among the groups ($P < 0.05$).

Conclusion. For IS patients with Cobb angles between 10° and 25°, our exercise protocol can effectively control or improve curve progression. Younger patients with a lower Risser grade are most likely to respond.

Key words: age, curve progression, efficacy, idiopathic scoliosis, intervention window, prospective controlled cohort study, Risser sign, specific exercise.

Level of Evidence: 2

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Idiopathic scoliosis (IS) is a rare spinal deformity affecting children, and the cause is still unknown. It is characterized by one or more three-dimensional spinal curves.[1,2] IS has negative effects on physical and psychosocial health, such as pulmonary complications, pain, and psychological disorders.[3,4] Actively intervention is necessary to prevent and correct IS progression. Various treatments are currently available on an individual basis, including watchful waiting, physiotherapy, bracing, and surgery.[1,5] The prescribed treatment varies depending on curve severity. IS severity is commonly evaluated by measuring the Cobb angle. It is generally agreed that curves up to 25° are mild curves, whereas severe curves measure have a

Cobb angle ≥45°.[1,6] For mild cases and those with a low risk of progression, physical therapy is recommended as the first line of treatment.[1,7] In a good-quality randomized controlled trail (n = 110)[8] and a fair-quality nonrandomized trial (n = 74),[9] the intervention group that completed tailored physiotherapeutic scoliosis-specific exercise experienced significant improvement compared with a generic-exercise control group at the 12-month follow-up.[10] This suggests that scoliosis-specific exercises may postpone or even prevent surgery and reduce the duration or degree of bracing,[11,12] especially for patients with single low-medium degree curves during growth.[6,13] Many scoliosis-specific physical exercise programs or rehabilitation treatments are recommended in Europe and the United States.[14,15] The programs include the SEAS (Scientific Exercise Approach to Scoliosis), BSPTS (Barcelona Scoliosis Physical Therapy School), FITS (Functional Individual Therapy of Scoliosis) Lyon exercises, and the Schroth method.[16,17] However, we still lack sufficient evidence to demonstrate the efficacy of physiotherapeutic scoliosis-specific exercises, and the therapeutic window remains unclear. There is also no assessment in specific for curve progression in patients of different ages.

This article introduces a unique approach that applies physiotherapeutic scoliosis-specific exercises from the Xinmiao treatment system (XTS), which consists of two parts: daily corrective postures and intensive corrective exercises. We applied this training system for mild progressive patients (10°–25°), mature patients refusing surgery or bracing, postoperative patients with junctional problems, or brace treatment patients. The aim of the study was to verify the efficacy of the XTS and compare correction efficacies among different age groups.

MATERIALS AND METHODS

Study Design

This prospective controlled cohort study was conducted the Guangdong Xinmiao Scoliosis Center database, including all patients treated between August 2013 and September 2017. Data were collected during everyday clinical practice. The participants were told about IS pathology and disease history, and a qualified technician or professional doctor explained treatment choices and outcomes at different stages before treatment. Thus, each patient had full knowledge and understanding of the significance to strengthen their muscles and stabilizes their spine in active self-correction. The therapy mainly consists of 2 types of exercises as showed in Figure 1A–G: one is daily life corrective postures

Figure 1. A subject participating in the XTS training. (**A** and **B**) Clinical image and radiographs before therapy. (**C**) The Scolioscan 3D ultrasound imaging system. (**D**) The subject being checked for correcting the daily life postures. (**E**) The example of intensive corrective exercises by stretching action movements. (**F**) The volume projection images obtained by Scolioscan before the training. (**G**)Volume projection images obtained by Scolioscan with the XTS corrective training.

TABLE 1. Patient Characteristics

	Number (n)	Sex F/M	Age, y	Mean Age ± SD, y	Mean Cobb Angle ± SD		Wilcoxn Signed-rank Test	Mean Risser Grade ± SD	Angle Correction in Degrees ± SD (Percentages %)
					Primary	After Treatment	*P*	Primary	
A	29	14/15	<10	8.2 ± 0.8	15.7 ± 4.4	8.9 ± 6.1*	<0.01	0	6.8 ± 5.5 (44)
B	24	21/3	10–12	11.5 ± 0.8	15.4 ± 4.0	12.3 ± 3.9**	<0.01	1.96 ± 1.3	3.1 ± 4.2 (18)
C	46	31/15	13–15	13.6 ± 0.8	14.7 ± 3.6	13.2 ± 5.5**	0.03	2.35 ± 0.9	1.5 ± 4.8 (9)

*$P < 0.01$, vs. primary.
**$P < 0.05$, vs. primary.

(including standing and sitting), the other is intensive corrective exercises (*e.g.*, muscle strengthening and curve stretching action movements). The patients were checked the correction with Scolioscan(a 3D ultrasound imaging assessment system)[18] to ensure the effectiveness of the training in a timely way. They needed to train for at least 40 minutes each day. We trained every patient and their parents for 1 to 2 days and instructed them to perform the exercises at home or school. Considering the subjects' different learning capabilities, we confirmed that they understood the training method 2 weeks later. Each participant visited the outpatient clinic every 3 to 4 months, and regular contact was maintained via the WeChat app (a widely used Chinese multi-purpose messaging, social media app in smart phones; patients or their parents could download the training voice message, videos, pictures, or text information) to answer any questions. All of the patients were only treated with the XTS.

Participants

The inclusion criteria were: IS was newly diagnosed without any treatment, Cobb angle between 10° to 25°, 3) Risser sign ≤grade 3, and at least 1-year follow-up. The exclusion criteria were: evidence of congenital curve;neuromuscular, cardiovascular or respiratory dysfunction diseases; systemic illness; cognitive impairment; bracing or surgical correction history. Ninety-nine patients (33 males, 66 females) met the inclusion criteria. The age range was 7 to 15 years, and the largest Cobb angle was 24° (Table 1). We had 30 single curves (three right thoracic, 10 left thoracic, four right lumbar, and 13 left lumbar) and 69 double curves (49 right thoracic curve with left lumbar curve, and 20 left thoracic curve with right lumbar curve). Patients were divided into different groups according to age (group A: <10 years, n = 29; group B: 10–12 years, n = 24; group C: 13–15 years, n = 46).

Data Analysis

Cobb angles were evaluated at baseline, monitored every 3 to 4 months using Scolioscan (spine ultrasound), and confirmed by x-ray at 6-month intervals. Lines were drawn across the vertebral column on the upper surface of the superior vertebra and the lower surface of the inferior vertebra. The angle measured was either that between these two lines or that between lines drawn perpendicular to them. To reduce the possibility of measurement errors, all radiographs were measured twice using the same protractor by one expert physician who was blinded to the subject data. Our results are the average of these two measurements. We also analyzed the number of patients who had clinically significant Cobb angle changes, setting the cut-off at 5°. The distribution of variables was first evaluated, and then a full set of paired sample comparisons employed, using parametric or nonparametric tests, as appropriate. Paired analysis of variance with post-hoc analysis was performed to compare Cobb degrees, and χ^2 testing and Fisher exact test were used to compare the results among the groups. This study was conducted in compliance with SOSORT criteria published by the International Scientific Society on Scoliosis Orthopaedic and Rehabilitation Treatment.[19]

RESULTS

The mean observation period was 2.08 years (range 1–5). Forty patients completed treatment, and 59 are continuing. No patient underwent bracing or scoliosis surgery. Tables 1–3 shows the characteristics of the participants in different groups. The results obtained in overall group were statistically significant ($P < 0.01$).

TABLE 2. Numbers and Percentage Values of IS Improvement, Stabilization, and Progression

	Improvement		Stabilization		Progression	
	n	Percentage	n	Percentage	n	Percentage
A	20	69.0%*	8	27.6%*	1	3.4%*
B	11	45.8%	12	50.0%	1	4.2%
C	12	26.1%	29	63.0%	5	10.9%

IS indicates idiopathic scoliosis.
*$P < 0.01$, vs. C.

TABLE 3. Patient Characteristics Grouped by Risser Sign

Risser Grade	n	Mean Age ± SD, y	Mean Cobb Angle ± SD		Follow-up ± SD, mo	Main Curve Improvement ± SD (Percentages %)	Improvement		Stabilization		Progression	
			Pre-treatment	Post-treatment			n	Percentage	n	Percentage	n	Percentage
0	37	8.9 ± 1.5	16.0 ± 4.2	10.3 ± 6.3**	29.6 ± 11.2	5.7 ± 5.6 (37)$^{\Delta,\#}$	23	62.2%$^{\#}$	12	32.4%$^{\#}$	2	5.4%$^{\#}$
1–2	23	13.0 ± 0.9	14.5 ± 3.9	12.5 ± 5.6*	34.5 ± 12.2	2.0 ± 4.8 (13)	9	39.1%	12	52.2%	2	8.7%
3	39	13.2 ± 1.1	14.7 ± 3.7	12.6 ± 4.7*	38.9 ± 10.9	2.1 ± 4.7 (12)	11	28.2%	25	64.1%	3	7.7%

*$P < 0.05$.
**$P < 0.01$ vs. pre-treatment.
$^{\Delta}P < 0.05$, vs. 1–2.
$^{\#}P < 0.05$, vs. 3.

In group A (29 patients, age <10 years), the average Cobb angle decreased from 15.7° to 8.9° for a curve correction of 6.8°. Overall, 69.0% (20 cases) of patients improved by >5°, 27.6% (8 cases) stabilized, and 3.4% (1 cases) experienced progression >5° (Table 2). The results were statistically significant compaired with group C ($P < 0.01$).

In group B (24 patients), the average Cobb angle decreased from 15.4° to 12.3°. We found that 45.8% (11 cases) of patients improved by >5°, 50% (12 cases) stabilized, and 4.2% (1 case) progressed 5° (Table 2).

In group C (46 patients), patients were aged 13 to 15 years, and the average Cobb angle decreased from 14.7° to 13.2° after treatment. In this group, 26.1% (12 cases) of patients improved by >5°, 63.0% (29) stabilized, and 10.9% (5) experienced Cobb angle progression of Cobb angle >5° (Table 2).

Table 3 shows the results of retrospective analysis of the correlation and effectiveness for different Risser grades. We included 37 patients with Risser sign grade 0 for whom the average Cobb angle improved by 5.7° from a pretreatment value of 16°. Overall, 62.2% (23 cases) of patients improved by >5°, 32.4% (12 cases) stabilized, and 5.4% (2 cases) experienced Cobb angle progression >5°. In the grade 3 group, only 28.2% (11 cases) of patients improved, and the mean angle correction was only 2.1° (12%). There was a statistically significant difference between the two groups ($P < 0.05$). Among Grade 1–2 patients, 39.1% (9 cases) improved, 52.2% (12 cases) stabilized, and 8.7% (2 cases) progressed. However, there were no statistically significant differences compared with the other two Risser Grade groups.

Regarding the differences between sexes, we retrospectively analyzed the correlations and effectiveness for males and females (Table 4). Among 33 male patients, 45.5% (15 cases) improved by >5°, 45.5% stabilized, and 9.1% progressed >5°. Among the 66 female patients, 42.4% had improved Cobb angle, 51.5% (34 cases) stabilized, and 6.1% (four cases) progressed. There were no statistically significant differences between males and females. Besides, we further divided both groups into subgroups according to the age (Table 5). In subgroup A1 (15 male patients, age <10 years), 73.3% (11 cases) of male patients improved by >5°, 26.7% (four cases) stabilized, and no case progressed. An analysis of variance indicated that there were statistically significant differences compared with subgroup C1 (male patients, 13–15 years) ($P < 0.01$). Among the female patients, the subgroup A2, 64.2% (nine cases) of male patients improved by >5°. Although it was much higer than

TABLE 4. Patient Characteristics Grouped by Sex

	n	Main curve before treatment ± SD°	Mean age ± SD, y	Mean Risser grade ± SD	Follow-up ± SD, mo	Main Curve Improvement ± SD (percentages %)	Improvement		Stabilization		Progression	
							n	Percentage	n	Percentage	n	Percentage
Male	33	15.2 ± 4.3	11.1 ± 2.9	1.3 ± 1.4	35.2 ± 9.8	4.7 ± 6.2 (28.4)	15	45.5%	15	45.5%	3	9.1%
Female	66	15.1 ± 3.8	11.8 ± 2.2	1.7 ± 1.3	34.4 ± 12.9	2.8 ± 4.8 (17.9)	28	42.4%	34	51.5%	4	6.1%

TABLE 5. Numbers and Percentage Values of IS Improvement, Stabilization, and Progression Grouped by Age and Sex Seperately

Male								Female							
	Improvement		Stabilization		Progression		]Main curve improvement ± SD (Percentages %)		Improvement		Stabilization		Progression		Main Curve Improvement ± SD (Percentages %)
	n	Percentage	n	Percentage	N	Percentage			n	Percentage	n	Percentage	n	Percentage	
A1	11	73.3%*	4	26.7%*	0	0*	8.9 ± 5.2 (52.7)*	A2	9	64.2%	4	28.6%	1	7.1%	4.6 ± 5.0 (32.0)
B1	1	33.3%	2	66.7%	0	4.8%	3.3 ± 2.5 (22.7)	B2	10	47.6%	10	47.6%	1	4.8%	3.0 ± 4.6 (19.4)
C1	3	20.0%	9	60.0%	3	20.0%	0.8 ± 4.8 (5.9)	C2	9	29.0%	20	64.5%	2	6.5%	1.8 ± 4.8 (11.8)

IS indicates idiopathic scoliosis.
*$P < 0.05$, vs. C1.

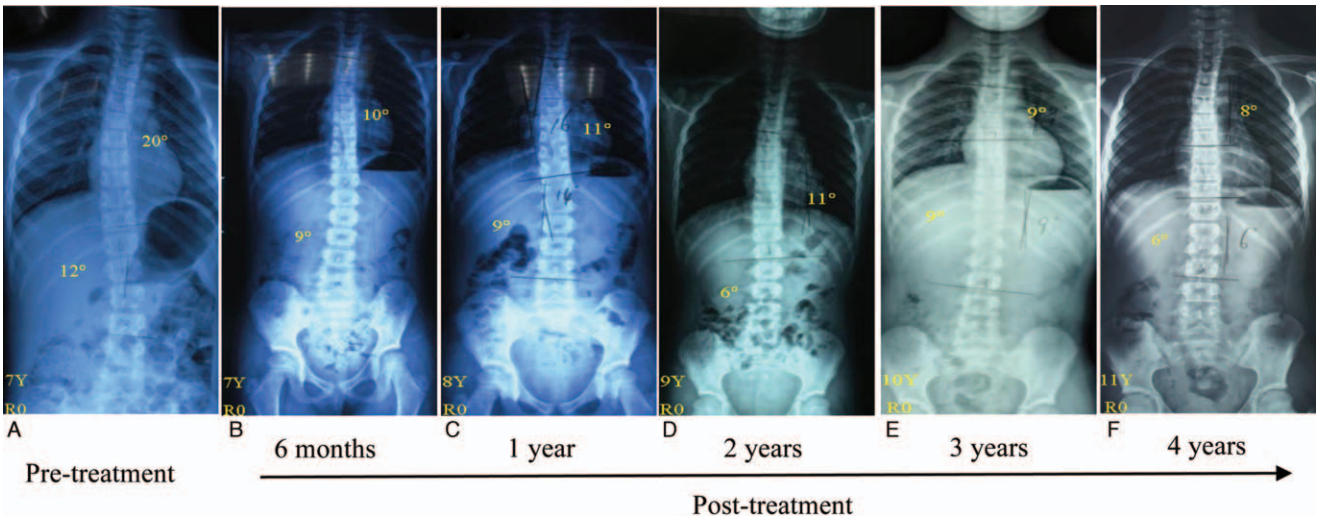

Figure 2. Group A example case. (**A**–**F**). x-Rays showing changes from before treatment through 4 years of follow-up show the Cobb angle decreased from 20° (Risser grade 0) at age 7 to 8° at age 11 (Risser grade 0).

that of subgroup B2 and C2, However, there were no statistically significant differences.

Case Presentation

Figures 2 to 4 show the courses of typical cases from each group, each patient was a newly diagnosed patient with a Cobb angle from 10° to 25°, and Risser grade 0 to 3. All three patients only completed the XTS protocol (>3 days/week, >1 h/day; no other treatment).

DISCUSSION

For IS patients whose Cobb angle is <25°, many doctors may recommend a wait-and-see approach with regular clinic visits. However, some patients (especially females) can progress in a very short time (Figure 5A–C).[1] The risk of health and social problems in adulthood increases significantly if scoliosis surpasses a critical threshold of 30°.[20] Therefore, early interventions can be of great significance to improve quality of life.

Many studies have reported the efficacy of physiotherapy treatment for IS.[8,9,11] The latest USPSTF (US Preventive Services Task Force) recommendation and the SRS/POSNA/AAOS/AAP position statement agree that available treatments (bracing, physiotherapeutic scoliosis-specific exercise) can interrupt or slow curvature progression in adolescence. The recommendation has been changed from "D" to "I" for scoliosis screening based on the evidence report and systematic review.[21] As mentioned by some authors,[15,22,23] specific personalized exercises are more effective than usual care with respect to reducing the progression rate and avoiding bracing. According to a prospective historical cohort-matched study of braced adolescent IS

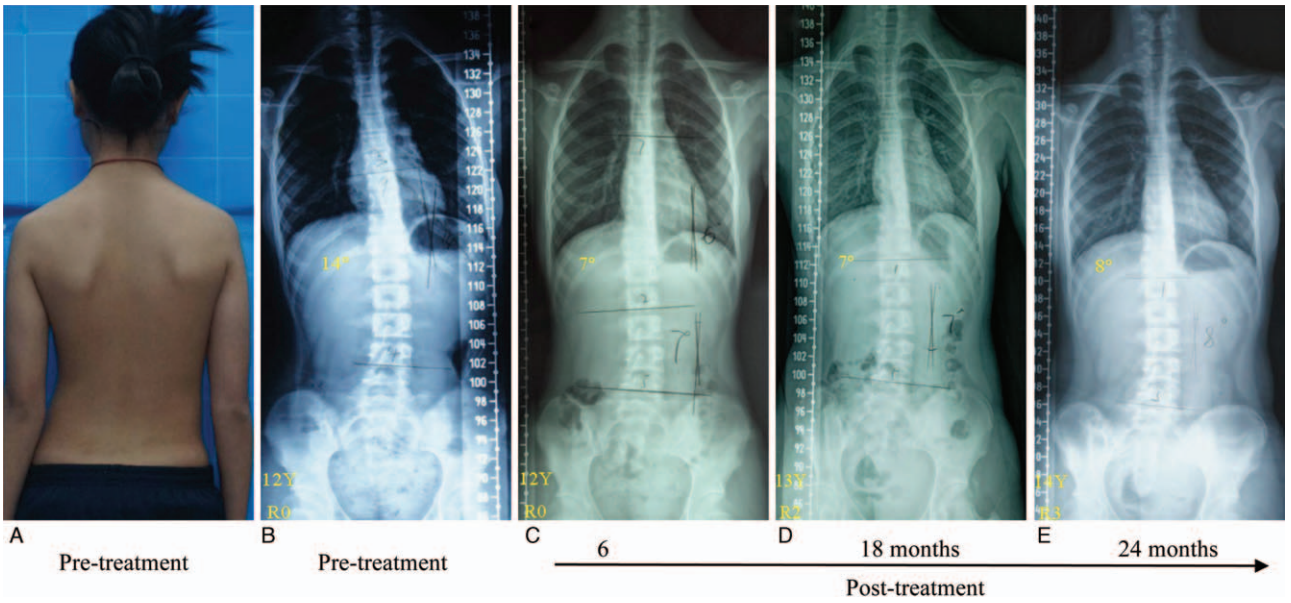

Figure 3. Group B example case. (**A**–**E**) x-Rays showing changes from before treatment through 2 years of follow-up show the Cobb angle decreased from 14° (Risser grade 0) at age 12 to 8° at age 14 (Risser grade 3).

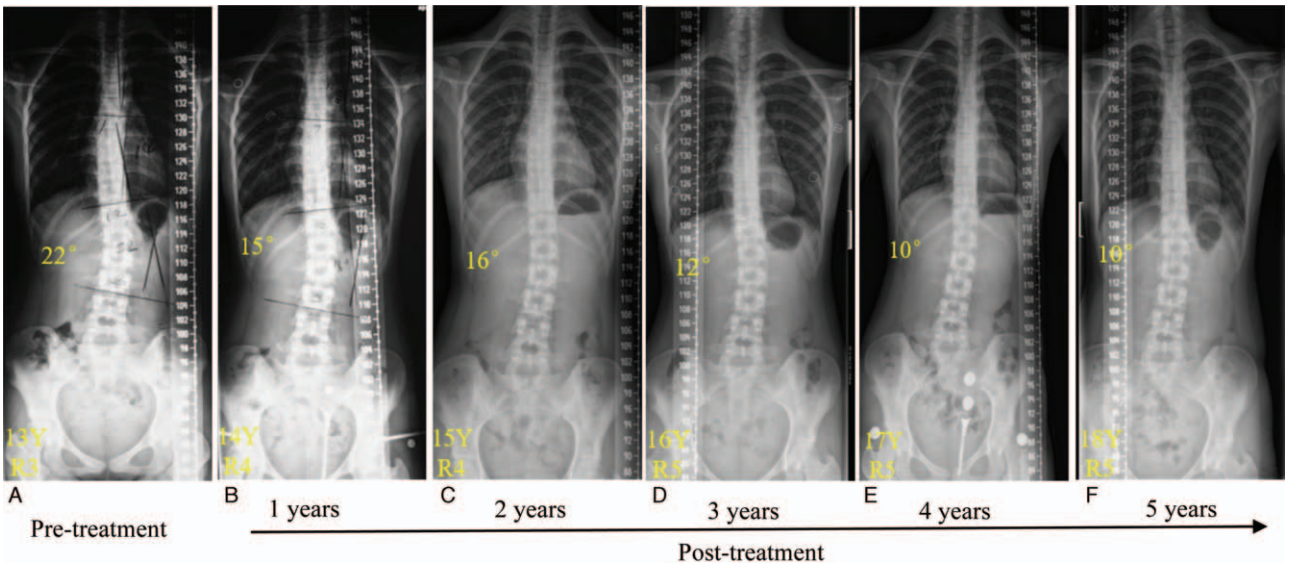

Figure 4. Group C example case. (**A**–**F**) x-Rays showing changes from before treatment through 5 years of follow-up show the Cobb angle decreased from 22° (Risser grade 3) at age 12 to 10° at age 18 (Risser grade 5).

patients, adding specific exercises was superior to bracing alone in improving Cobb angles and trunk rotation.[24] Exercises have no obvious disadvantages and can also achieve some other important objectives such as improved neuromotor control, respiratory function, and spinal stability. However, no controlled prospective cohort study has considered age as a grouping factor with respect to the radiographic results for IS patients. Moreover, most study databases and exercise approaches originate from western countries; few were from Asia, let alone southern China. To understand whether exercises are truly capable of exerting a positive influence, we carried out the prospective controlled cohort observational study.

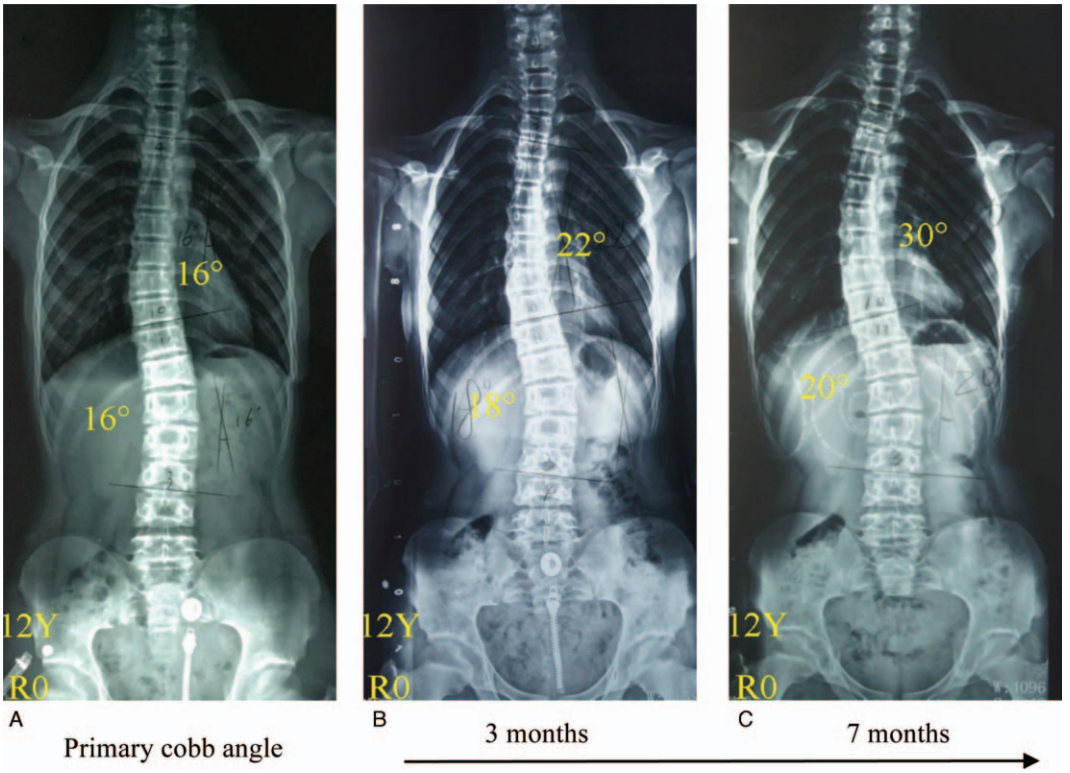

Figure 5. Rapid progression example case. (**A**–**C**) x-Rays showing that the Cobb angle increased from 16° to 30° within 7 months (Risser grade 0 for both time points).

All of the enrolled cases were skeletally immature, so it was possible to affect the curve progression through exercise training. As the indications or contraindications were unclear in previous work,[12] we carried applied strict standards for patient recruitment, and patients with contraindications were excluded. All patients were observed by the same physicians and strictly carried out standardized and personalized exercises according to the XTS. Contact was maintained with the WeChat app and at regular outpatient visits. The patients and their parents were carefully queried regarding how many hours per day they had exercised as instructed, and the average compliance was recorded. Long-term, continuous, regular exercising requires collaboration and motivation, and we took special care to improve compliance. All measurements were made twice by the same expert physicians, and we used the average of the two measurements to reduce the probability of error. The treating physicians and physiotherapists were not aware that the study was being performed; they were focused only on the patients' needs and strictly implemented the treatment protocols.

In our study, patients performing exercises according to the XTS protocols achieved very good clinical results, with only seven patients worsening (only two patients exceeded $>10^\circ$ Cobb). Almost half (43.4%) of cases had curve improvement, 49.5% were stable, and 7.1% had progressed at 1-year follow-up. We found that 69.0% (20 cases) of the patients in group A improved by $>5^\circ$. The outcomes suggest that the XTS protocol followed in the study is effective in preventing curve progression for young patients, and they confirm the previously published improvements in patients with IS who completed exercise treatment.[15,25,26] We measured a curve correction of 6.8° in group A. This is similar to results published by Otman *et al*,[26] who reported that the mean Cobb angle decreased by 6.85° after 6 months following the Schroth method. In another prospective controlled cohort study, Negrini *et al*[15] concluded that 23.5% improved with SEAS exercises, whereas 11.8% worsened. However, the results are not comparable because of differences in methodology and patient selection. As the Risser sign grade is a reference designator of skeletal maturity, we also retrospectively analyzed the correlation and effectiveness for different Risser grades. Although some studies reported that skeletal growth rates may mismatch with curve progression,[27,28] we found that Risser sign grade 0 patients had better outcomes than grade 3 patients, with 37% and 12% improving, respectively.

Many reasons could explain the efficacy of the XTS. Initially, the exercises protocols can maintain or restore anti-gravity trunk muscles (*e.g.*, paravertebral muscles) and reduce the asymmetrical load, so the spinal vertebral return to relative balance. The exercises may also facilitate better vertebrae growth by reducing postural collapse.[29] According to Hueter-Volkmann's law, compression and traction can inhibit and accelerate vertebral growth, respectively. The force of compression or traction changes with long-term targeted exercises. Additionally, the immature skeleton of younger subjects are more amenable to altering growth on the concave and convex sides of the vertebrae. The surrounding soft tissue also has more elasticity to strengthen or restore. Finally, older child may have poor compliance to the exercise treatment due to youth rebellion and the high homework burden in China.

According to the natural history of idiopathic scoliosis, the rate of spinal curvature changes most rappidly in periods of growth spurt, especially at the beginning of puberty.[19] Both the clinicians and patients need to be aware of the risk of curve progression.[1] Considering the functional and psychological concerns into adulthood, early intervention is of great significance for those patients during the time window. The goal of intervention in early phase is to prevent curve progression. Our study supports the use of XTS exercises until skeletal maturity. It shows spinal deformities progressed in only 7% of the overall subjects, much less than the estimated 20% to 60% risk of progression of the age.[30]Meanwhile, the result is better than many previous reports with physiotherapy treatment, and is quite similar to 8% progression of the experimental group from a randomized controlled trial.[8]

Our results should be considered in the context of the study limitations. Although we assessed the effectiveness of the approach using follow-up data and imaging, we did not include a general exercise group or some other training approach (*e.g.*, SEAS or Schroth). The study was carried out at a single center with a relatively small sample size, which might bias the findings. A long-term, prospective, multicenter study is needed to confirm our results.

In conclusion, the results of this study confirm that the XTS can effectively control or improve curve progression for IS patients with a Cobb angle between 10° and 25°. Our novel exercise therapy is more effective for younger patients with a lower Risser sign grade.

➢ Key Points

- ❑ Xinmiao treatment system can effectively control or improve curve progression for the mild IS patients.
- ❑ The novel exercise therapy is more effective for younger IS patients with a lower Risser sign grade.

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