Schroth exercises improve health-related quality of life and radiographic parameters in adolescent idiopathic scoliosis patients

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Abstract

Background: Finding an optimal treatment strategy for adolescent idiopathic scoliosis (AIS) patients remains challenging because of its intrinsic complexity. For mild to moderate scoliosis patients with lower skeletal growth potential (Risser 3–5), most clinicians agree with observation treatment; however, the curve progression that occurs during puberty, the adolescent period, and even in adulthood, remains a challenging issue for clinicians. The aim of the study is to investigate the efficacy of Schroth exercise in AIS patients with lower skeletal growth potential (Risser 3–5) and moderate scoliosis (Cobb angle 20°–40°).

Methods: From 2015 to 2017, data of 64 patients diagnosed with AIS in Peking University Third Hospital were reviewed. Forty-three patients underwent Schroth exercise were classified as Schroth group, and 21 patients underwent observation were classified as observation group. Outcomes were measured by health-related quality of life (HRQOL) and radiographic parameters. HRQOL was assessed using the visual analog scale (VAS) scores for back, Scoliosis Research Society-22 (SRS-22) patient questionnaire. Radiographic spinopelvic parameters were obtained from anteroposterior and lateral X-rays. The pre-treatment and post-treatment HRQOL and radiographic parameters were tested to validate Schroth exercise efficacy. The inter-rater reliability of the radiographic parameters was tested using the interclass correlation coefficient (ICC). The paired *t* test was used to examine HRQOL and radiographic parameters. Clinical relevance between C2-C7 sagittal vertical axis (SVA) and thoracic kyphosis was analyzed using Spearman correlation.

Results: In Schroth group, VAS back score, SRS-22 pain, and SRS-22 self-image domain were significantly improved from pre-treatment 3.0 ± 0.8, 3.6 ± 0.5, and 3.5 ± 0.7 to post-treatment 1.6 ± 0.6 ($t = 5.578$, $P = 0.013$), 4.0 ± 0.3 ($t = -3.918$, $P = 0.001$), and 3.7 ± 0.4 ($t = -6.468$, $P < 0.001$), respectively. No significant improvements of SRS-22 function domain ($t = -2.825$, $P = 0.088$) and mental health domain ($t = -3.174$, $P = 0.061$) were observed. The mean Cobb angle decreased from $28.9 \pm 5.5°$ to $26.3 \pm 5.2°$ at the final follow-up, despite no statistical significance was observed ($t = 1.853$, $P = 0.102$). The mean C2-C7 SVA value decreased from 21.7 ± 8.4 mm to 17.0 ± 8.0 mm ($t = -1.224$ $P = 0.049$) and mean T1 tilt decreased from 4.9 ± 4.2 ° to $3.5 \pm 3.1°$ ($t = 2.913$, $P = 0.011$). No significant improvement of radiographic parameters and HRQOL were observed in observation group.

Conclusions: For AIS patients with a Risser 3–5 and a Cobb angle 20°–40°, Schroth exercises improved HRQOL and halted curve progression during the follow-up period. Both cervical spine alignment and shoulder balance were also significantly improved after Schroth exercises. We recommend Schroth exercises for patients with AIS.

Keywords: Adolescent idiopathic scoliosis; Schroth exercises; Health-related quality of life; Curve progression; Cervical alignment

Introduction

Adolescent idiopathic scoliosis (AIS) is the most common type of scoliosis. However, finding an optimal treatment strategy remains challenging because of its intrinsic complexity. Age, sex, skeletal maturity, Cobb angle, menarche status, and other factors should be considered during clinical evaluation.[1] Non-operative treatment is recommended for patients with a major curve less than 45° according to the Scoliosis Research Society (SRS) criteria, and brace treatment is strongly recommended to halt curve progression in patients with a Risser sign 0–2 with moderate scoliosis due to its rapid skeletal growth.[2]

For mild to moderate scoliosis patients with lower skeletal growth potential (Risser 3–5), most clinicians agree with observation treatment; however, the curve progression that occurs during puberty, the adolescent period, and even in adulthood, remains a challenging issue for clinicians.[3-5] Watanabe *et al*[6] further validated this viewpoint in a mean 25-year follow-up and provided an explicit value −0.5° per year. Moreover, decline of health-related quality of life (HRQOL) was also observed, indicating that a

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strategy with the possibility of long-term sustainability is needed to eliminate this concern.

The effectiveness of physical therapy for improving HRQOL and halting curve progression has been well established in AIS patients with mild scoliosis.[7-9] However, its outcomes in patients with lower skeletal growth potential (Risser 3–5) and larger curvatures remain unknown. Schreiber *et al*[10] investigated Schroth exercises–physiotherapeutic scoliosis-specific exercises in patients with curve angles from 10° to 45° and found improvements in HRQOL. Nevertheless, Schroth exercises were unable to reduce the Cobb angle in this study. A limitation of Schreiber study was the lack of a Risser sign description, which is important for skeletal growth potential evaluation. Therefore, our study attempted to validate the effectiveness of Schroth exercises in patients with lower skeletal growth potential (Risser 3–5) and moderate scoliosis (20°–40°).[11]

Methods

Ethical approval

This study was approved by Peking University Third Hospital (No. M2017406). All procedures performed in studies involving human participants were in accordance with the ethical standards of the Peking University Third Hospital research committee and with the *1964 Helsinki Declaration* and its later amendments or comparable ethical standards. Given the retrospective nature of the study, the requirement of written informed consent was waived.

Inclusion criteria and exclusion criteria of Schroth group

Electronic database of Peking University Third Hospital was retrospectively reviewed. Patients treated between January 2015 and December 2017 were enrolled. The inclusion criteria were as follows: 1) a primary diagnosis of AIS in patients aged between 10 and 17 years; 2) a Risser sign of 3, 4, or 5; 3) a Cobb angle between 20° and 40°; 4) performance of Schroth exercises during intensive training, and adherence to a home exercise program; 5) a minimum 2-year follow-up was achieved; and 6) the availability of complete radiographs.

The exclusion criteria were as follows: 1) prior brace treatment history; 2) prior physical exercise history; 3) prior surgical treatment; 4) cardiac and/or respiratory dysfunction; 5) other types of scoliosis; and 6) psychiatric disease (hysteria, psychosis, and others).

Inclusion criteria and exclusion criteria of observation group

The data of patients under observation was also reviewed as observation group. The inclusion criteria were as follows: 1) a primary diagnosis of AIS in patients aged between 10 and 17 years; 2) a Risser sign of 3, 4, or 5; 3) a Cobb angle between 20° and 40°; 4) a minimum 2-year follow-up was achieved; and 5) the availability of complete radiographs. The exclusion criteria were as follows: 1) prior brace treatment history; 2) prior physical exercise history; 3) prior surgical treatment; 4) cardiac and/or respiratory dysfunction; 5) other types of scoliosis; and 6) psychiatric disease (hysteria, psychosis, and others).

Schroth exercise treatment

The Schroth exercises were performed according to the Barcelona Scoliosis Physical Therapy School protocol. Auto elongation, asymmetrical sagittal straightening, frontal plane correction, rotational angular breathing, and stabilization variations were the primary principles. Patients received breath-training exercise, muscle strength control exercise, body-shape correction exercise, and balancing capacity exercise [Supplementary videos 1–4, http://links.lww.com/CM9/A809, http://links.lww.com/CM9/A810, http://links.lww.com/CM9/A811, http://links.lww.com/CM9/A812].

During winter vacation/summer vacation, patients first underwent a 14-day intensive training program supervised by certificated physical therapists [Figure 1]. After intensive training, patients continued self-exercise through a home exercise program that was supervised by parents. The training frequency was set to two or three times per week for 1 hour.

Assessments

HRQOL was assessed using the SRS-22 patient questionnaire, which consists of five domains: function, pain, mental health, self-image, and satisfaction with management. The results were expressed as the mean score for each domain. Visual Analog Scale (VAS) scores for back pain were also noted. Data were extracted from the electronic database containing original medical records.

Scoliosis progression was evaluated using the Cobb angle. Radiographic parameters were as follows:

1) Global spine parameters: coronal vertical axis (CVA) and sagittal vertical axis (SVA);
2) Cervical spine parameters: C2-C7 Cobb angle and C2-7 SVA;
3) Thoracic and lumbar spine parameters: lumbar lordosis (LL), thoracic kyphosis (TK), and thoracolumbar kyphosis (TLK); and
4) Shoulder balance parameters: coracoid height difference (CHD), clavicular angle (Cla-A), and T1 tilt [Figure 2].

All parameters were obtained from anteroposterior and lateral X-rays that were obtained from the electronic database. The parameters were measured independently by two spine surgeons using the Picture Archiving and Communication System (PACS system, GE, Waukesha, WI, USA), and the mean values were recorded.

Statistical analysis

Clinical and radiographic data were analyzed using the Statistical Package for the Social Sciences version 22.0 (SPSS, Inc., Chicago, IL, USA). The inter-rater reliability of the radiographic parameters was tested using

Figure 1: Illustration of Schroth exercises. (A) Patients received breath-training exercise; (B) patients received muscle strength control exercise; (C) patients received active body-shape correction exercise; and (D) patients received muscle strength and balancing capacity exercise.

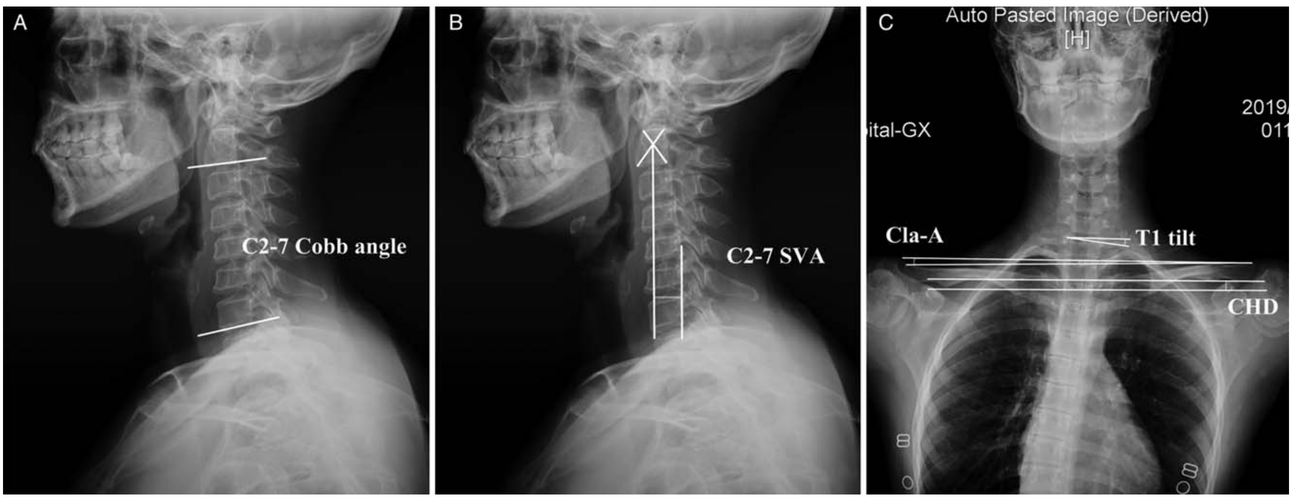

Figure 2: Illustration of radiographic parameters. (A) C2-7 Cobb angle is defined as Cobb angle measurement between the inferior end plate of the C2 and C7; (B) C2-7 SVA is defined as the distance between the C2 plumb line and C7 supero-posterior corner; (C) T1 tilt is defined as the angle between the upper margin of T1 and horizontal line; Cla-A is defined as the angle between the line connecting the highest points of the clavicles and the horizontal line; and CHD is defined as the height difference between the horizontal lines through the upper margin of each coracoid process. C2-7 SVA: C2-7 sagittal vertical axis; CHD: coracoid height difference; Cla-A: clavicular angle.

the interclass correlation coefficient (ICC). The paired *t* test was used to compare pre-operative and post-operative HRQOL and radiographic parameters. Clinical relevance between C2-C7 SVA and TK was analyzed using Spearman correlation. Statistical significance was considered at a P value < 0.05.

Results

Patient characteristics

Between January 2015 and December 2017, 43 patients (7 boys, 36 girls) with a mean age of 15.1 ± 1.6 (range, 13–17) years were classified as Schroth group. The mean follow-up period was 31.9 ± 8.2 (range, 25–52) months.

Among this population, the apical vertebra was located in T7 in five cases, T8 in four cases, T9 in three cases, T10 in two cases, T11 in five cases, T12 in seven cases, L1 in six cases, L1/2 in five cases, and L2 in six cases.

Risser sign was recorded as follows: Risser sign 3 was observed in nine patients, Risser sign 4 in 19, and Risser sign 5 in 15 patients.

Twenty-one patients (4 boys, 17 girls) with a mean age of 15.8 ± 1.5 (range, 13–17) years were classified as observation group. The mean follow-up period was 33.1 ± 6.2 (range, 25–41) months.

Among this population, the apical vertebra was T7 in three cases, T8 in one case, T10 in two cases, T11 in five cases, T12 in five cases, L1 in two cases, L1/2 in two cases, and L2 in one case.

Risser sign was recorded as follows: Risser sign 3 was observed in five patients, Risser sign 4 in 12 patients, and Risser sign 5 in four patients.

Effect of Schroth exercises on HRQOL

VAS back and SRS-22 pain domain scores were significantly improved after the Schroth exercise program as evidenced by decreases in the mean VAS scores (pre-treatment: 3.0 ± 0.8 [range, 2–4]; post-treatment: (1.6 ± 0.6 [range, 1–3]; $t = 5.578$, $P = 0.013$) and improvements in the mean SRS-22 pain scores (pre-treatment: 3.6 ± 0.5 [range, 3.0–4.2]; post-treatment: 4.0 ± 0.3 [range, 3.4–4.4]; $t = -3.918$, $P = 0.001$). The SRS self-image scores improved from 3.5 ± 0.7 (range, 2.8–4.0) pre-treatment to 3.7 ± 0.4 (range, 3.0–4.4) post-treatment ($t = -6.468$, $P < 0.001$) [Table 1].

The SRS-22 mental health (pre-treatment: 4.0 ± 0.3 [range, 3.2–4.4]; post-treatment: 4.1 ± 0.2 [range, 3.6–4.4]) and function scores (pre-treatment: 3.9 ± 0.2 [range, 3.4–4.4]); post-treatment: 4.1 ± 0.2 [range, 3.6–4.4]) improved after the Schroth exercise program; however, the differences were not statistically significant [Table 1].

In observation group, no significant improvement of HRQOL was observed [Table 2].

Effect of Schroth exercises on radiographic parameters

The inter-rater ICC values of the radiographic parameters are shown in Table 3. After the Schroth exercise treatment, the average Cobb angle decreased from 28.9°±5.5° (range, 21.1°–36.4°) to 26.3°±5.2° (range, 19.8°–36.3°) at the final follow-up, but the difference was not statistically significant. Six patients experienced curve progression with a mean curve progression of 1.2°±1.1° (range, 0.3°–2.4°) per year. No patient was the candidate of surgery during the follow-up period [Figure 3].

After Schroth exercises, the average C2-C7 SVA value decreased significantly from 21.7 ± 8.4 mm (range, 11.7–42.2 mm) to 17.0 ± 8.0 mm (range, 10.7–35.5 mm) at the final follow-up ($t = 2.144$, $P = 0.049$); however, the C2-C7 Cobb angle values were not significantly different before and after Schroth exercises ($t = -1.224$, $P = 0.240$). The correlation between C2-C7 SVA value variation and TK value variation was not confirmed by Spearman correlation analysis ($P = 0.991$).

Among parameters of shoulder balance, the mean T1 tilt decreased from 4.9°±4.2° (range, 0.4°–14.7°) to 3.5°±3.1° (range, 0.3°–11.9°) at the final follow-up ($t = 2.913$, $P = 0.011$); however, CHD and Cla-A values were not significantly different before and after Schroth exercises [Table 3].

The differences between pre- and post-treatment SVA, CVA, TK, TLK, and LL values were not statistically significant [Table 3]. The data of observation group were shown in Table 4, and no statistical difference of radiographic parameters was observed.

Table 1: HRQOL of Schroth group before exercise and at final follow-up ($n = 43$).

Parameters	Pre-exercise	Final follow-up	t	P
VAS back	3.0 ± 0.8	1.6 ± 0.6	5.578	0.013
SRS-22				
Pain	3.6 ± 0.5	4.0 ± 0.3	−3.918	0.001
Function	3.9 ± 0.2	4.1 ± 0.2	−2.825	0.088
Mental health	4.0 ± 0.3	4.1 ± 0.2	−3.174	0.061
Self-image	3.5 ± 0.7	3.7 ± 0.4	−6.468	<0.001
Satisfaction	–	4.3 ± 0.3	–	–

–: Not applicable. HRQOL: Health-related quality of life; SRS: Scoliosis Research Society; VAS: visual analog score.

Table 2: HRQOL of observation group ($n = 21$).

Parameters	First visit	Final follow-up	t	P
VAS back	3.1 ± 0.7	3.0 ± 0.6	−2.213	0.121
SRS-22				
Pain	3.6 ± 0.5	3.5 ± 0.8	−2.821	0.231
Function	4.0 ± 0.3	3.9 ± 0.4	−2.523	0.131
Mental health	4.0 ± 0.5	4.1 ± 0.3	−3.421	0.295
Self-image	3.5 ± 0.8	3.4 ± 0.7	1.041	0.415
Satisfaction	–	4.1 ± 0.6	–	–

–: not applicable. HRQOL: Health-related quality of life; SRS: Scoliosis Research Society; VAS: visual analog score.

Table 3: Radiographic parameters of Schroth group before exercise and at final follow-up ($n = 43$).

Parameters	Pre-exercise	Inter-rater ICC	Final follow-up	Inter-rater ICC	*t*	*P*
Cobb angle (°)	28.9 ± 5.5	0.913	26.3 ± 5.2	0.922	1.853	0.084
SVA (mm)	−14.96 (−35.0–4.9)	0.881	−11.7 (−30.1–7.1)	0.901	−0.255	0.802
CVA (mm)	15.6 ± 10.7	0.931	12.7 ± 8.3	0.921	1.005	0.215
C2-C7 Cobb angle (°)	6.5 ± 11.4	0.873	3.5 ± 7.6	0.832	−1.224	0.240
C2-C7 SVA (mm)	21.7 ± 8.4	0.852	17.0 ± 8.0	0.864	2.144	0.049*
LL (°)	48.7 ± 8.0	0.926	52.0 ± 13.3	0.931	1.267	0.224
TK (°)	17.9 ± 7.1	0.910	19.7 ± 5.6	0.873	−1.037	0.316
TLK (°)	6.4 (3.6–18.3)	0.857	7.3 (2.6–13.0)	0.878	1.241	0.127
CHD (mm)	4.7 (3.2–11.2)	0.821	5.1 (1.7–7.6)	0.819	0.957	0.355
Cla-A (°)	2.0 ± 1.6	0.813	1.6 (0.3–4.2)	0.821	0.893	0.493
T1 tilt (°)	4.9 ± 4.2	0.926	3.5 ± 3.1	0.934	2.913	0.011*

* Pre-exercise *vs*. final follow-up. C2-C7 SVA: C2-C7 sagittal vertical axis; CHD: Coracoid height difference; Cla-A: Clavicular angle; CVA: Coronal vertical axis; ICC: Interclass correlation coefficient; LL: Lumbar lordosis; SVA: sagIttal vertical axis; TK: Thoracic kyphosis; TLK: Thoracolumbar kyohosis.

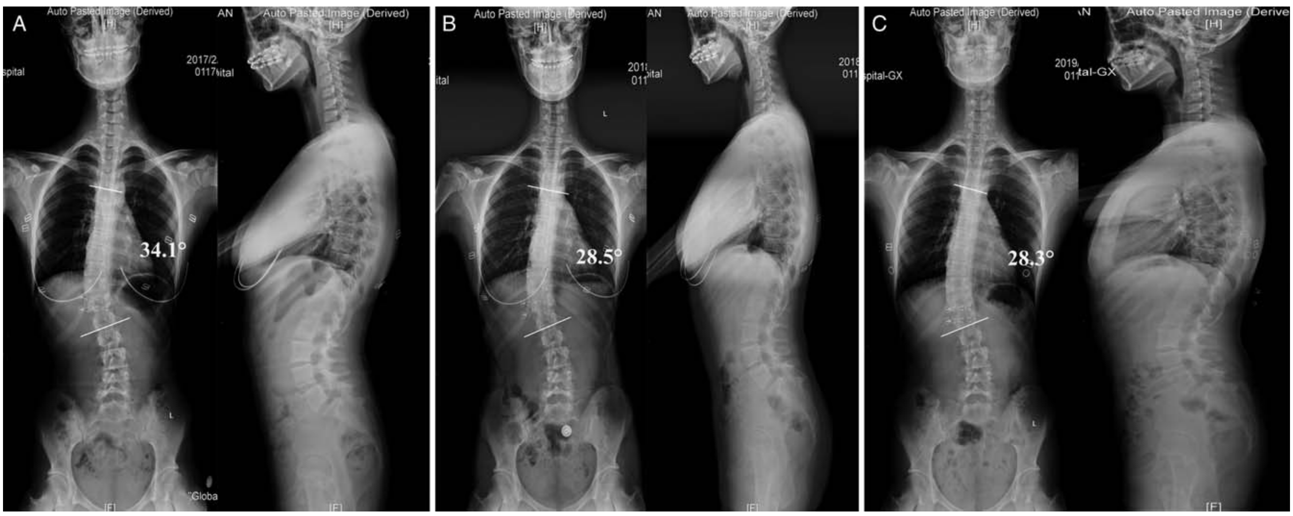

Figure 3: A 15-year-old girl with Risser 3 performed Schroth exercises. (A) Pre-treatment Cobb angle was 34.1° on X-ray; (B) after 1-year Schroth exercise, Cobb angle decreased to 28.5° on X-ray; and (C) after 28-month Schroth exercise, Cobb angle was 28.3°.

Discussion

The decline in HRQOL and curve progression were two major concerns in the previous publications on AIS conservative treatment, and a strategy with long-term sustainability was needed to dispel these concerns. Both improvements of HRQOL and halt of curve progression after Schroth exercises were validated in this preliminary study, providing some new viewpoints concerning AIS conservative treatment.

Effect of Schroth exercises on HRQOL improvement

Multiple strategies are used to manage non-surgery candidate AIS patients, including observation, bracing, and physical exercise, and the effectiveness of physical exercise is ambiguous.[12] Kuru *et al*[13] reported that no definite HRQOL (SRS-23) improvement was observed in patients with a wide range of scoliosis severity (10°–60°) and Risser sign 0–3. However, Monticone *et al*[9] reported better satisfying HRQOL improvements with physical exercise in mild scoliosis patients, and Schreiber *et al*[14] also advocated that mild to moderate scoliosis patients with all grades of Risser sign could benefit from Schroth exercises, with SRS-22 pain and self-image domains improvements. We speculated that the causes of the discrepancy were the scoliosis severity of the cohorts included in the previous studies and the heterogeneity of the growth potential.

To reduce the potential bias of a heterogeneous cohort, we set thresholds for the Cobb angle between 20°–40° and only included patients with lower skeletal growth potential (Risser 3–5), which ruled out patients strongly recommended for brace treatment by the SRS and the International Society on Scoliosis Orthopaedic and

Table 4: Radiographic parameters of observation group ($n=21$).

Parameters	First visit	Inter-rater ICC	Final follow-up	Inter-rater ICC	t	P
Cobb angle (°)	27.8 ± 4.1	0.942	28.1 ± 5.2	0.931	1.871	0.102
SVA (mm)	−12.2 (−32.1–4.2)	0.901	−12.7 ± 21.4	0.891	−0.231	0.702
CVA (mm)	14.6 ± 9.7	0.913	14.7 ± 8.3	0.912	0.512	0.625
C2-C7 cobb angle (°)	6.6 (4.5–14.2)	0.833	6.8 ± 11.9	0.873	−1.328	0.740
C2-C7 SVA (mm)	22.7 ± 9.4	0.872	22.4 ± 8.0	0.846	1.812	0.781
LL (°)	48.5 ± 8.2	0.957	49.0 ± 12.1	0.875	2.323	0.724
TK (°)	17.9 ± 7.0	0.857	18.1 ± 6.6	0.821	2.012	0.526
TLK (°)	11.1 ± 7.1	0.827	10.8 ± 6.1	0.818	1.854	0.327
CHD (mm)	5.8 ± 4.0	0.813	6.2 ± 5.1	0.899	0.762	0.405
Cla-A (°)	1.5 ± 1.4	0.814	1.4 ± 1.1	0.841	0.962	0.413
T1 tilt (°)	5.1 ± 3.8	0.826	5.2 ± 4.1	0.901	2.014	0.412

*First visit *vs.* final follow-up. C2-C7 SVA: C2-C7 sagittal vertical axis; CHD: Coracoid height difference; Cla-A: Clavicular angle ; CVA, Coronal vertical axis; ICC: Interclass correlation coefficient; LL: Lumbar lordosis; SVA: Sagittal vertical axis; TK: Thoracic kyphosis; TLK: Thoracolumbar kyohosis.

Rehabilitation Treatment guidelines. In our study, good outcomes were observed: VAS scores for back pain decreased notably, while the mean SRS-22 pain and self-image domains improved significantly after treatment.

Although mild pain is reported in mild to moderate scoliosis,[12,14] relatively higher pain values were observed in this study, and pain values (VAS back score and SRS-22 pain domain) improved successfully after treatment. We speculated that one possible reason was the onset of long sitting study time in AIS patients. Shan *et al*[15] investigated the neck and shoulder pain (NSP) in high school teenagers, and more than 40% adolescents reported NSP resulting from schooling factors related to study. Based on the relatively similar age onset to this study, we speculated that relatively higher pain values resulted not only from scoliosis but also their fatigue postures related to study, indicating some social factors should also be taken into consideration for improving HRQOL of AIS patients, not only deformity itself. Thus, we considered Schroth exercises rather than observation-only to strengthen and balance their muscles which may have contributed to their pain relief.

Aiming to investigate self-image assessment in adulthood, Watanabe *et al*[6] found significantly worse scores for the SRS-22 self-image domain in all types of scoliosis groups. Yet, Schreiber was the first to validate SRS-22 self-image domain improvements with Schroth exercises.[14] A similar finding was observed in our study, i.e., the mean SRS-22 self-image domain also improved after Schroth exercises, indicating that such exercises were effective for correcting the appearances of both sagittal and frontal asymmetries. We assumed that the latent worse self-image scores in the previous study originated from scoliosis, indicating that a treatment strategy is required to provide long-term sustainability. Compared to the restriction of spine motion by rigid brace treatment, we considered Schroth exercise procedures as a self-traction and self-releasing program, achieved by positional guidance exercise and muscle strength exercise. Both effectiveness of HRQOL improvement and long-term sustainability were achieved, indicating that Schroth exercises were effective for the early treatment of AIS patients with mild scoliosis; however, a long-term follow-up study is still necessary.

Effect of Schroth exercises on preventing curve progression

Bracing is not recommended for patients with a Risser sign of 3–5 due to their lower skeletal growth potential. Moreover, the effectiveness of further treatment strategies for patients with a Cobb angle <45° is ambiguous, [12] and observation is recommended for most patients. However, curve progression was reported to be inevitable after skeletal maturity, with a mean Cobb angle progression from baseline 29.2°–29.3° to 35.0°–37.8° in adulthood.[4,11]

Monticone *et al*[9] found that the Cobb angle decreased from 19.3° to 14.3° in patients with skeletal immaturity (Risser 0–2) after physical exercise. Although the Cobb angle at the last follow-up was lower than the baseline value, no statistical significance was observed. We speculated that the real value of Schroth exercises for moderate AIS patients was to halt curve progression rather than reduce the curve, but a further study was needed to validate this viewpoint.

Effect of Schroth exercises on shoulder balance and cervical sagittal alignment parameters

Etiology and pathogenesis of AIS is indefinite, and asymmetric alteration of paravertebral muscle may cause the inharmony of posture.[16] Regarding shoulder balance, few studies have clarified its relationship with AIS after physical therapy.[17] Zheng *et al*[17] found no statistically significant improvements in shoulder balance parameters (CHD, Cla-A, and T1 tilt) in the exercise group, whereas the bracing group experienced significant improvements. Notably, in our study, T1 tilt was significantly improved whereas CHD and Cla-A were not. Kwan[18] advocated that T1 tilt was a parameter associated with neck tilt rather than shoulder balance, and our findings indicated that neck tilt was improved rather shoulder balance in this hypothesis. However, this theory was not supported by other authors.

Chiu *et al*[19] reported that conformity values varied for different shoulder balance statuses, and T1 tilt showed the best conformity with shoulder balance. We inferred that shoulder balance status could be improved by the identification of T1 tilt value variation, and the finding that CHD and Cla-A values were not significantly improved was attributed to its intrinsic conformity. Thus, further studies are needed to clarify this issue.

Few investigators have studied cervical sagittal alignment and physical exercise. This study is the first to report that C2-C7 SVA could be significantly improved by Schroth exercises. Akbar *et al*[20] demonstrated that cervical kyphosis is associated with hypokyphotic thoracic alignment, and Neuman *et al*[21] further validated that reciprocal changes in cervical alignment are associated with TK. In contrast to their findings, no correlation between the improvements in C2-C7 SVA and TK values and significant changes in TK values were detected in our study. Consequently, we speculated that the improvement in cervical alignment resulted from the cumulative exercise effects of asymmetrical sagittal straightening and muscle strength improvement rather than as a result of reciprocal changes in TK. Accordingly, cervical spine malalignment may be corrected using Schroth exercises, and we advocate Schroth exercises as an ideal treatment strategy for AIS patients.

This study has several limitations. Firstly, it was retrospective and conducted at a single centre. Secondly, this was a preliminary study of Schroth exercises with a minimum 2-year follow-up, and a study with a 10-year follow-up is still needed to validate its effectiveness. Finally, some other physical exercises should also be studied in further investigations.

For AIS patients with a Risser 3–5 and a Cobb angle 20°–40°, Schroth exercises improved HRQOL and halted curve progression during the follow-up period. Both cervical spine alignment and shoulder balance were also significantly improved after Schroth exercises. We recommend Schroth exercises for patients with AIS.

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Conflicts of interest

None.

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