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# A Pilot Study on the Effect of Outpatient Schroth Exercises on Thoracolumbar and Lumbar Curves in Adult Scoliosis Patients

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Additional information is available at the end of the chapter

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## Abstract

**Study design:** This is a pilot prospective cohort study.

**Objectives:** To investigate if outpatient Schroth exercises (SBP) affect thoracolumbar or lumbar curves in adult scoliosis patients.

**Background:** Adult scoliosis tends to progress and is associated with an increased prevalence of low back pain. The outcome of conservative treatment is not satisfactory, as treatment is not directed towards spinal deformity. This study investigates if SBP influences the thoracolumbar and lumbar curves in patients with adult scoliosis.

**Materials and methods:** Adult patients with thoracolumbar and lumbar curves  $\geq 20^\circ$  were taught SBP exercises once weekly for 4 weeks. They then performed the exercises at home three times a week, for 9 months. Baseline measurements included Cobb angles, coronal offset, sagittal vertical axis (SVA), T4-12 kyphosis, L1-S1 lordosis, sacral slope, pelvic incidence and pelvic tilt. They were compared to post-intervention measurements, using paired t tests.

**Results:** SBP exercises statistically significantly decreased the Cobb angle ( $p = 0.0032$ ), improved the ATR ( $p = 0.012$ ), increased the sacral slope ( $p = 0.03$ ), decreased the pelvic tilt ( $p = 0.0032$ ) and the SVA ( $p = 0.032$ ).

**Conclusion:** The SBP exercises improved the Cobb angles and SVA in adult scoliosis patients with thoracolumbar and lumbar curves.

**Keywords:** adult scoliosis, adult idiopathic scoliosis, degenerative lumbar scoliosis, Schroth exercises, physiotherapeutic scoliosis specific exercises, scoliosis rehabilitation

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## 1. Introduction

Scoliosis is a three-dimensional spinal deformity with a lateral curvature in excess of  $10^\circ$ . Adult scoliosis refers to scoliosis after skeletal maturity. It can arise from a wide range of conditions, including neuromuscular diseases, metabolic diseases, trauma, etc. Most commonly, the condition includes adult idiopathic scoliosis and degenerative lumbar scoliosis (DLS) [1–3], which are discrete conditions. Sometimes they coexist and are difficult to distinguish.

Adult scoliosis is increasing in importance in recent years, as its prevalence is increasing, as a result of increased life expectancy of the population [2, 3]. Adult scoliosis with thoracolumbar and lumbar curves is associated with a higher prevalence of low back pain. Also, they tend to progress. Many adult AIS patients consult because of the progression of their curves or of symptoms that decrease their quality of life inducing functional impairment [4]. Thoracolumbar curves receive the highest percentage of surgical treatment among adult coronal deformities; it accounted for 32.6% of all surgeries for adult scoliosis [5].

Apart from causing low back pain, thoracolumbar and lumbar curves tend to progress. Weinstein and Ponseti showed that 68% of the AIS curves progressed after skeletal maturity, especially when the Cobb angle exceeds  $30^\circ$  [6, 7]. In a retrospective study on progression of adult scoliosis, Marty-Poumarat et al. found that curves in adult AIS as well as DLS patients' progress, irrespective of the initial Cobb angle [8]. The rate of progression for lumbar or thoracolumbar single curve was  $0.82^\circ/\text{year}$  ( $0.34\text{--}1.65^\circ$ ) for adult AIS patients and  $1.64^\circ/\text{year}$  ( $0.77\text{--}3.82^\circ$ ) for DLS patients, respectively. Similarly, Iida et al. reported that AIS patients with thoracolumbar and lumbar curves (Lenke 5C) with a Cobb angle over  $30^\circ$  have a high risk of progression [9].

Symptomatic adult scoliosis patients are generally treated conservatively by NSAIDs, analgesics, manipulation, acupuncture, and electrotherapy [10]. These conservative treatments have not been found to be effective [11]. Everett and Patel found a low level of evidence in support of conservative treatment. They identified level IV evidence for physical therapy, chiropractic care, and bracing and level III evidence for steroid injections [11]. Similarly, Glassman et al. assessed the cost associated with nonsurgical treatment of adult scoliosis and found that despite the substantial mean cost of US\$10,815 per patient, there was no improvement in any HRQOL (Health-Related Quality of Life) measure over 2-year follow-up [12].

The unsatisfactory outcome of the treatment approach is possibly due to the fact that it targets at the symptoms of the adult scoliosis, but not the spinal deformities which are the one of the causes of the symptoms. The present study attempts to investigate whether Schroth best practice (SBP) exercises, which have been found to improve curves in AIS patients [13–18], do affect thoracolumbar and lumbar curves in adult scoliosis patients.

## 2. Materials and methods

### 2.1. Patient selection

Adult scoliosis patients with AIS and degenerative lumbar scoliosis of either sex, who were aged 20–70 years and were seen in the Wanchai Chiropractic Clinic were included. Patients

with lumbar spondylolisthesis, congenital scoliosis, syndromic scoliosis, functional scoliosis due to leg length discrepancy and secondary scoliosis due to antalgia, and compression fractures were excluded.

## 2.2. Procedures

Consecutive adult scoliosis patients consulted for low back pain between January 2014 and October 2015 in the Wanchai Chiropractic Clinic, with signs of thoracolumbar or lumbar scoliosis were referred for standing postero-anterior (PA) full spine radiographs. When the Cobb angle was  $\geq 20^\circ$  and the apex of the curve lied in the thoracolumbar or lumbar area, the subject would be asked for consent to participate in the study and was then referred for standing full spine lateral radiograph.

The angle of trunk rotation (ATR) of the patients was measured. The subjects then completed the Chinese version of the SRS-22 which has been found to have satisfactory internal consistency and excellent reproducibility [19]. They were then instructed to perform the SBP exercises [20, 21], which essentially involve holding the lumbar spine in lordosis and horizontally translating the trunk to the side of the lumbar convexity, whilst simultaneously lowering the contralateral pelvis to deflex the lumbar spine. The subjects then breathed into the areas of concavities [22] and exhaled forcefully with isometric contraction of all the trunk muscles [22]. The breathing method is termed “rotational angular breathing (RAB)” and is an inherent part of the Schroth exercise approach [22]. Corrective postures to be undertaken during daily activities [21, 23, 24] were also taught by a certified SBP therapist.

The subjects took four weekly classes. They then performed the exercises at home for at least three times a week and adopted corrective postures basing on their curve types [21, 23] and the side of the curves during daily activities. They had to mark on their log book the dates they did the exercises. They returned quarterly for assessment to see if they had been performing the exercises correctly.

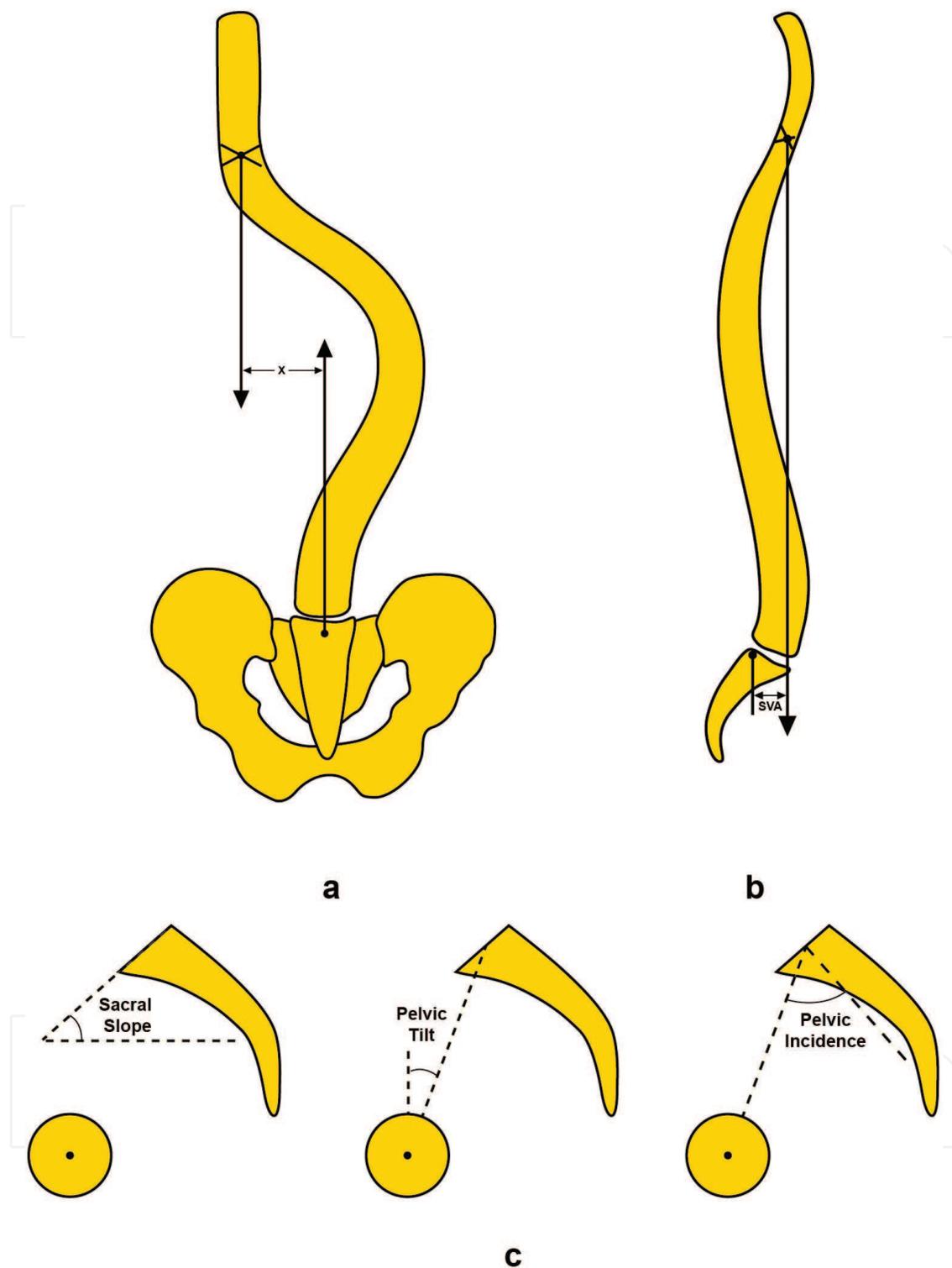
The subjects were advised not to take up any sports or activities that they did not do prior to the intervention nor engage in any therapy and/or treatments targeted to the spinal deformities, as these might confound the outcome.

After 9 months, PA and lateral full spine X-rays of the patients were again taken and the ATR measured. The patient filled in the Chinese version of SRS-22 again.

## 2.3. Measurement of radiographs

All the radiographs were scanned, masked, and coded before being measured by an independent radiologist at the end of the study to avoid measurement bias. The Surgimap software was used for measurement, as it had been found to have good to excellent inter and intraobserver reliability [25].

The coronal Cobb angle, coronal offset, T4-T12 kyphosis, T10-L2 kyphosis, L1-S1 lordosis, sacral slope, pelvic tilt, pelvic incidence [26, 27], and C7-S1 sagittal vertical axis (SVA) [28, 29] were measured (**Figure 1**). The coronal offset, which is the distance from the center of C7 to the vertical line drawn from the center of the sacrum (central sacral line CSL), was also



**Figure 1.** Measurements of the radiographic parameters. (a) “x” stands for the coronal offset. It is the distance between the center of the body of C7 and a perpendicular line from the center of sacrum (CSL). When C7 is situated to the right of CSL, the measurement was designated at “-;” otherwise it was regarded as “+.” (b) SVA stands for sagittal vertebral axis. It is the distance between a perpendicular line from the center of the body of C7 to the superoposterior corner of S1. When the line is in front of the superoposterior corner of S1, the measurement was regarded as “+;” otherwise it was regarded as “-.” (c) The measurements of other spinopelvic parameters.

determined. When C7 is to the right of CSL, the measurement was designated as negative “-;” otherwise it was regarded as positive “+.” The SVA, which was the distance between the perpendicular line from the body of C7 to the superoposterior corner of sacrum, was measured. When the perpendicular dropped in front of the superoposterior corner of the sacrum, the measurement was regarded as positive “+,” otherwise it was regarded as negative “-“. Measurements of spinopelvic parameters which included the sacral slope, pelvic tilt and pelvic incidence were performed as previously described by Schwab et al. and Glassman et al. [28, 29].

## 2.4. Statistical analysis

The post-intervention Cobb angles, the coronal offset, sacral slope, pelvic tilt, pelvic incidence, L1-S1 lordosis, T10-L2 kyphosis, T4-12 kyphosis, the pelvic incidence-lumbar lordosis (PI-LL) mismatch, and C7-S1 SVA were compared to the baseline measurements. Paired t tests were conducted to determine whether the post- and pre-intervention difference was statistically significant at  $p < 0.05$ . Similar statistical analysis was performed for ATR as well as SRS-22 domain scores.

## 3. Results

Twenty-three patients with thoracolumbar or lumbar scoliosis were enrolled into the study. Six dropped out soon after consent for various reasons (**Figure 2**). This left 17 patients. All of them followed the study protocol. Near the end of the study, five patients went overseas for study and work and were not available for final assessment. Finally, only 12 patients’ data were collected for the present analysis.

Eleven of the 12 patients are female, with a mean age of  $45.9 \pm 15.0$ . Two had thoracolumbar curve, with apex at L1. The other 10 had lumbar curves, with apex at L2 or L3. Three had curves to the right and 9 had curves to the left (**Table 1**). All but one complained of chronic low back pain. One had recovered from an acute low back pain episode three weeks prior to enrolment on the program and was pain-free at the commencement of the study. Nine of the patients had adult idiopathic scoliosis, one had adult idiopathic scoliosis with DLS and two had DLS.

### 3.1. Cobb angle

The mean baseline Cobb angle was  $31.2 \pm 9.6^\circ$ , which dropped to  $27 \pm 7.4^\circ$  after 9 months. Based on the criterion that a reduction of  $6^\circ$  Cobb angle represents improvement [30], four subjects had improvement of the curves. The improvement rate is thus 33.3%. Pre- and post-intervention paired t test showed that  $p = 0.0032$ , which was statistically very significant (**Table 2**).

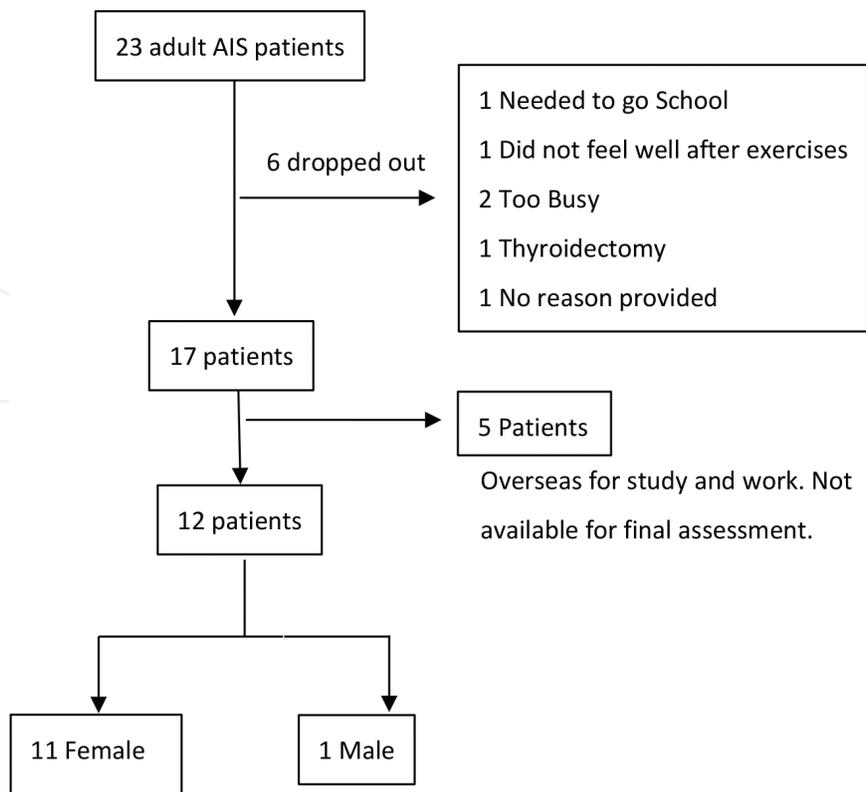


Figure 2. The flowchart of adult scoliosis patients.

Patient	Age	Sex	S/C	Range of curve		Apex		Types of scoliosis
				Initial	9 months	Initial	9 months	
1	24	F	L	T11-L4	T10-L4	L2	L2	AIS
2	56	F	L	L1-L4	L1-L4	L3	L3	AIS+DLS
3	51	F	L	L2-L5	L1-L4	L3	L2	AIS
4	58	F	L	T12-L4	L1-L4	L2	L2-L3	DLS
5	41	F	L	L1-L4	L1-L4	L3	L3	AIS
6	61	F	L	T12-L4	T12-L4	L2	L2	AIS
7	70	F	R	T12-L3	T12-L4	L2	L2	DLS
8	43	F	R	T10-L4	T10-L4	L2	L1	AIS
9	31	F	L	T11-L4	T10-L4	L1	T12	AIS
10	24	M	L	L1-L4	L1-L4	L3	L3	AIS
11	37	F	R	T12-L4	T12-L4	L1	L1	AIS
12	55	F	L	T12-L4	T12-L4	L2	L2	AIS
Mean	45.9							
SD	15							

S/C, side of convexity; AIS, adult idiopathic scoliosis; DLS, degenerative lumbar scoliosis.

Table 1. The age, sex, and the curve characteristics of the subjects.

Subjects	Cobb angle (°)			Coronal offset (mm)	
	Initial	9 months	Change	Initial	9 months
1	24	23	-1	6.8	3.6
2	43	33	-10	-8.8	-10.8
3	24	23.5	-0.5	2.3	3.8
4	43	31.5	-11.5	1.9	-7.6
5	28	24	-4	7.1	6
6	21	20	-1	-1	-1.4
7	26	23	-3	-2.7	-4.6
8	42	36	-6	-10.5	-11.7
9	42	37	-5	7.2	9.1
10	27	20	-7	4.1	-0.5
11	17	16	-1	-2.8	-2.3
12	37	37	0	11.6	10
Mean	31.17	27	-4.17	5.57	4.6
SD	9.58	7.4	3.84	3.58	5.5
P-value	0.0032*			0.35	

\* Statistical significance.

**Table 2.** The Cobb angle and the coronal offset (the distance between the centre of C7 from the central sacral line) at baseline and conclusion of the study .

### 3.2. Coronal offset

Seven curves had C7 offset to the left of CSL and 5 had offset to the right at baseline. After 9 months, four subjects in the former group had reduced coronal imbalance and three had increased coronal imbalance (**Figure 3**). For the latter group, four had an increase in coronal imbalance and only one had an improved coronal balance. The change in coronal offset, however, was not statistically significant (**Table 2**).

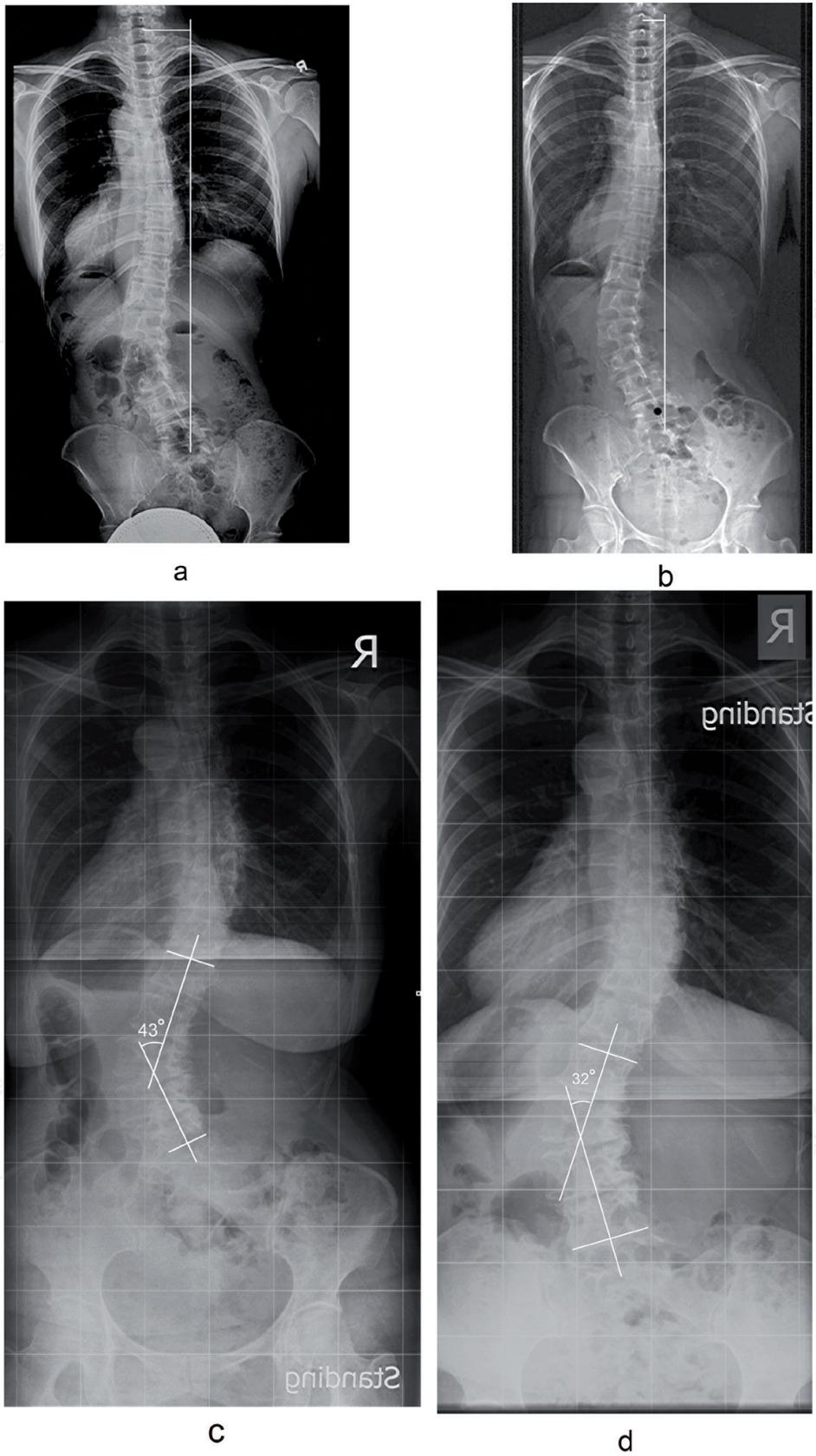
### 3.3. ATR measurement

Ten subjects had improvement of ATR after the program. Statistically, there was a significant difference between the baseline and post-intervention measurements ( $p = 0.0115$ ) (**Table 3**).

The reduction of ATR during RAB in a forward bending position was more marked, at  $2.08 \pm 1.83^\circ$  after the 9 months of training (**Table 3**). The difference was statistically very significant, with  $p = 0.0023$ .

### 3.4. T4-12 kyphosis, L1-S1 lumbar lordosis, T10-L2 kyphosis

In general, there was a trend toward a reduction in thoracic kyphosis. The change in lumbar lordosis and thoracolumbar kyphosis was not statistically significant (**Table 4**).



**Figure 3.** Posteroanterior full spine X-rays of a patient pre-intervention (a) and (b) post-intervention. It is noteworthy that her coronal balance improved. (c and d) The pre- and post-intervention X-rays of another patient, and the improvement of Cobb angle was noted.

	ATR°		ATR° in rotational angular breathing	
	Baseline	9 months	Baseline	9 months
1	7	5	4	0
2	21	21	19	15
3	11	10	8	5
4	13	9	10	6
5	10	9	7	6
6	9	11	6	7
7	12	11	9	7
8	16	13	9	9
9	21	19	18	17
10	6	4	2	2
11	5	1	4	0
12	23	15	16	13
Mean	12.83	10.67	9.33	7.25
SD	6.15	5.85	5.6	5.5
P-value		0.0115*		0.0023*

\*Statistical significance.

**Table 3.** Angle of trunk rotation (ATR) in normal and rotational angular breathing at baseline and conclusion of the study.

### 3.5. Sacral slope

Interestingly, 9 of 12 patients had an increase in sacral slope (**Table 4**). The post- and pre-intervention difference was statistically significant with  $p < 0.030$ .

### 3.6. Pelvic tilt

As the sacral slope increased, the extent of pelvic tilt would reduce, as the sum of sacral slope and pelvic tilt is equal to pelvic incidence, which is a constant (**Table 4**). Nine patients had a reduction in pelvic tilt. The difference between post- and pre-intervention was statistically very significant at  $p < 0.0032$ .

### 3.7. Sagittal vertical axis

After 9 months, the global sagittal balance of the spine improved, with reduction of the antero-posterior truncal shift toward a more neutral position. The post- and pre-intervention difference was statistically significant at  $p < 0.032$  (**Table 4**).

Patient	T4-12 kyphosis°		L1-5 lordosis°		T10-L2 kyphosis°		SS°		SVA (mm)		PI°		PT°		PI-LL°	
	B	9 months	B	9 months	B	9 months	B	9 months	B	9 months	B	9 months	B	9 months	B	9 months
1	45	41	45	46	6	4	23	25	-45	-42.5	42	40	19	15	-3	-6
2	8	1	4	12	51	55	17	23	108.7	67.3	62	64	45	41	58	52
3	42	41	28	28	30	31	15	18	85.3	26.3	33	32	18	14	5	4
4	11	25	32	43	-22	-21	21	33	-8.3	-6.1	44	47	23	14	12	4
5	17	6	33	32	12	7	36	45	30	-14	62	65	26	20	29	33
6	60	37	48	47	1	2	31	32	-12	-11.3	52	54	21	22	4	7
7	32	19	10	24	20	27	17	22	23.5	0	35	32	18	10	25	8
8	42	39	48	54	-16	-19	20	25	-46	-42.4	33	31	13	6	-15	-23
9	32	27	42	36	16	30	23	30	-32.8	-61.9	42	45	19	15	0	9
10	49	46	40	39	15	20	35	32	-22.1	0	52	48	17	16	12	9
11	13	18	48	50	-38	-18	38	33	2.7	-4.8	54	52	16	19	6	2
12	32	22	33	36	11	19	28	28	38	0	33	30	5	2	0	-6
Mean	31.9	26.8	34.3	37.3	7.2	11.4	25.3	28.8	10.2	-7.5	45.3	45.0	20.0	16.2	11.1	7.8
SD	16.6	14.4	14.5	12	23.8	23.4	8	7	49.2	33.5	10.9	12.4	9.4	9.7	1.9	1.9
p	0.083		0.097		0.066		0.03*		0.032*		0.68		0.0032*		0.114	

Subj, subjects; B, baseline; SS, sacral slope; SVA, sagittal vertical axis; PI, pelvic incidence; PT, pelvic tilt; PI-LL, pelvic incidence minus lumbar lordosis. Except for SVA, all measurements were in degrees.

\* Statistical significance.

**Table 4.** The pre- and post-intervention spinopelvic and global sagittal balance measurements .

Domains	Period	Subjects												Mean	SD	P-value
		1	2	3	4	5	6	7	8	9	10	11	12			
Function	Initial	4.4	3.6	4	3.8	3.6	3.6	4.2	4.4	4.4	4.6	4	4.2	4.07	0.36	0.49
	9 mths	4.6	2.8	4.6	3.8	4	3.8	4	5	5	4.8	4.2	4.4	4.17	0.61	
Pain	Initial	4.2	2.6	3	4	3.2	3.8	5	4.2	4.2	4.8	3.4	3.3	3.81	0.73	0.19
	9 mths	4.4	2.5	4.4	4.4	3.6	3.5	4.6	4.4	5	4	3.6	4.3	4.06	0.67	
Self-image	Initial	3.2	2.6	2.6	3	2.8	3	3.8	3.2	3.2	3	3.2	2.6	3.02	0.35	0.001*
	9 mths	3.6	2.4	4.2	4	3	3.4	4.2	3.6	3.8	3.8	3.6	3.4	3.58	0.51	
Mental health	Initial	4.2	3	3.4	4	3.2	4	4.4	3.8	3.6	4.4	4	2.6	3.72	0.57	0.04*
	9 mths	4.2	3	4.6	4.4	4	4	4.8	4.6	4.6	4.6	4.4	1.8	4.08	0.86	
Satisfaction/ dissatisfaction	Initial	4.5	4.5	4.5	3	4.5	3.5	4	3.5	4	4	3	2	3.42	1.33	0.018*
	9 mths	4.5	4.5	5	4.5	4	4.5	4.5	4	4	4.5	4.5	4.5	4.42	0.29	
Total score	Initial	4	3.1	3.4	3.6	3.3	3.6	4.1	3.9	3.9	4.2	3.6	3.1	3.65	0.38	0.0016*
	9 mths	4.2	2.9	4.5	4.2	3.7	3.8	4.4	4.4	4.5	4.3	4	3.5	4.03	0.48	

Mths, months.

\* Statistical significance

**Table 5.** The SRS-22 Score of the subjects pre- and post-intervention.

### 3.8. SRS-22

Comparing the baseline and the results at 9th month showed that there was no significant difference of scores in the function and pain domains (**Table 5**). There were, however, significant difference of scores for the self-image ( $p = 0.001$ ), mental health ( $p = 0.004$ ), and satisfaction/dissatisfaction domains (0.018). The difference in SRS-22 total score was also statistically different ( $p = 0.0016$ ).

## 4. Discussion

Overall, 9 months of home-based Schroth exercises significantly improved the Cobb angle, the ATR, the ATR during RAB, the sacral slope, the pelvic tilt, the sagittal vertical axis as well as SRS-22 scores.

### 4.1. Cobb angle

The SBP exercise improved the Cobb angle very significantly. This is consistent with previous findings [17, 20, 21, 31, 32] in AIS patients. Curves of adult AIS patients can be reduced through multi-modal rehabilitation approaches [13, 14, 16]. SEAS (Scientific Exercise Approach to Scoliosis Exercises) [15, 17], Schroth [18] and side shift exercises [31] have been reported to reduce curve severity in adult AIS patients. Negrini et al. reported an adult AIS female, aged 25 with a double curve, treated by SEAS for 1 year. The main lumbar curve reduced from 47 to 28.5° [15]. Similarly, Yang et al. reported an AIS adult female with thoracic Cobb angle of 20.51°, treated by stretching, SBP, and strengthening exercises. In 8 weeks, the Cobb angle reduced to 16.35° [18]. Side shift exercises were also reported to reduce the Cobb angle of 69 patients with a mean age of 16.3 years. After an average follow up of 4.2 years, the mean Cobb angle reduced from 31.5 to 30.3° [31]. A retrospective cohort study also showed that curves of adult AIS patients can be reduced through SEAS. After 2 years of intervention, 68% experienced an improvement which averaged 4.6°. On average, the thoracolumbar curve reduced by 3° and the lumbar curve reduced by 3.6°. The improvement, however, was not statistically significant [17]. In comparison, our results showed that the improvement rate was 33.3%, when 6° curve reduction was regarded as an improvement. The average improvement was 4.2°. The findings closely matched that of the study by Negrini et al. [17]. It has, however, to be noted that not all of the patients in the present study had adult AIS.

Interestingly, nonscoliosis specific exercises have also been found to improve the Cobb angle in AIS and DLS patients [32]. Fishman et al. found that performing side plank yoga pose with the curve convexity facing downwards, for as long as possible once daily for 3–22 months resulted in an improvement of the Cobb angle [32]. The side plank yoga pose improved the Cobb angle in the 12 patients with DLS, from an average of 50.4–33.1° [32]. Yet, the study has a number of weaknesses and limitations. The study included patients with Cobb angle as small as 6°. Strictly speaking, these patients should not be regarded as suffering from scoliosis. Also, a reduction of 3° Cobb was regarded as improvement, though curve improvement is defined as a reduction of 6° Cobb angle [30].

## 4.2. Coronal offset

Glassman et al., in a study in 2005, showed that a coronal imbalance of 4 cm is associated with deterioration of pain and function scores in unoperated patients [12]. Similarly, Ploumis et al. showed that a coronal imbalance of 5cm is associated with a reduction in functionality [33]. Also, trunk shift is a predictor of surgery for patients with thoracolumbar and lumbar curvatures [34]. Lafage et al., however, showed no correlation between clinical outcomes and coronal global balance [35]. The magnitude of the coronal deformity did not impact pain and disability [35].

In the present cohort, the largest coronal offset was only 11.6 mm at baseline (**Table 2**). At ninth month, seven patients had an increase in coronal imbalance but five had an improvement. Yet, the change was small and was possibly clinically insignificant. The worsening of the coronal imbalance in some of the subjects is believed to be a result of the compensation to realign the spine by reducing the Cobb angle. The increase did not reach statistical significance.

## 4.3. Angle of trunk rotation

The change in ATR was statistically significant. On average, the reduction was only 2.2°. This is less than that previously reported in AIS patients, which averaged 3–4° [20, 36]. The difference between our study and others may be related to the fact that their subjects were adolescents and had better spinal flexibility than the present cohort.

The difference in ATR when performing RAB in forward flexion between baseline and at ninth month was statistically very significant ( $p = 0.0023$ ). After 9 months of home-based training, the ATR during RAB reduced from a mean of 9.3–7.3°. The decrease of 2° is consistent with the findings by Borysov and Borysov in much younger patients [20].

We are not aware of any study that measured the ATR changes in adult scoliosis patients after performing PSSE and are therefore unable to make any comparison.

## 4.4. Sagittal balance and alignment

In recent years, the spinopelvic parameters and sagittal spinal balance have been found to be more important than the coronal curves in relation to clinical outcomes [26, 37–39]. Glassman et al. evaluated the relationships between radiographic parameters and health status. They found that the severity of symptoms is linearly related to the extent of sagittal spinal imbalance [29]. Anterior translation of the trunk, with the SVA in excess of 7 cm is associated with an increase in clinical symptoms [29]. Similarly, Lafage et al. showed a correlation between the SVA and Scoliosis Research Society (SRS) total scores and Oswestry Disability Index (ODI) [35]. Schwab et al. found that a SVA in excess of 47 mm, in combination with a pelvic tilt in excess of 22° and pelvic incidence-lumbar lordosis (PI-LL) mismatch in excess of 11° was closely correlated with disability [40].

The present study showed that SBP exercises did not impact the thoracic kyphosis and lumbar lordosis significantly. The findings concurred with previous findings [41, 42] in AIS patients. Weiss and Klein found that the Physio-logic® program did not improve the thoracic kyphosis [42] and Noh et al. found that Schroth exercises did not improve the thoracic kyphosis and

lumbar lordosis [41]. The findings are not unexpected, in view of the fact that the spine of adult scoliosis patients is generally more rigid than that of AIS patients and improvement of curves is less likely.

Yet, the present study found that SBP exercises increased the sacral slope, decreased the pelvic tilt, and improved the SVA significantly (**Table 4**). It is noteworthy that the improvement involved two of the three key radiographic parameters correlated with disabilities [40]. At baseline, the mean sacral slope was 25.3°, which is lower than the mean sacral slope of 39 and 40.9° reported in normal volunteers by Troyanovich et al. and Duval-Beaupere et al., respectively [43, 44]. Our results, however, compared well with the results reported by Iida et al. in adult scoliosis patients. They reported a sacral slope of 26.6° of the DLS patients group and 27.5° for the adult AIS group, respectively [9]. Yang et al. reported a mean sacral slope of 32° in the 99 adult patients with spinal deformities (ASD) with a median age of 67 years [45]. The difference between our data and that of other studies may be related to the magnitude of the scoliosis [9, 45], as progression of lumbar scoliosis has been found to reduce the sacral slope [35, 46].

Duval-Beaupere et al. suggested that a reduction in sacral slope reduced the stability of the pelvis [47]. At the conclusion of the study, the sacral slope increased significantly from a mean of 25.3–28.8°, suggesting that the intervention may improve the stability of the pelvis requiring less hip extensor activity to maintain balance [47].

The pelvic tilt reduced from 20 to 16.2° post intervention. The difference was statistically significant. A study has shown that a pelvic tilt angle of above 22° correlated with disability [43]. Similarly, a number of studies have shown that a large pelvic tilt is associated with increased pain and decreased function [35, 38]. A study which analyzed the pre and post-operative differences in spinopelvic parameters and their relationship to postoperative pain showed that patients with a larger postoperative pelvic tilt were likely to have postoperative residual pain than patients with a smaller postoperative pelvic tilt [38]. Similarly, Lafage et al. showed clear evidence that an increased pelvic tilt was associated with increased pain and decreased function [35]. Thus, the reduction of pelvic tilt after intervention may be associated with a better clinical outcome.

PI-LL mismatch has also been found to strongly correlate with disability [40]. A mismatch suggests that the lumbar lordosis does not compensate adequately [40]. The mismatch is clinically significant when it is in excess of 10°. At baseline, 5 had PI-LL mismatch, whereas after 9 months, only 2 had any significant PI-LL mismatch. Yet, the pre- and post-intervention differences were not statistically significant.

Positive sagittal spinal imbalance has also been found to correlate with the severity of symptoms and disability [29, 40]. Duval-Beaupere et al. showed that an anterior translation of the center of gravity in excess of 30 mm in front of the coxofemoral joints require the contraction of the hip extensors for balance [44]. This may be related to the increase in symptoms in patients with positive sagittal spinal imbalance. In the present study, it was shown that the SVA reduced significantly after intervention, suggesting that the patients had an improved global sagittal spinal balance. This may be clinically significant as Schwab et al. showed that a SVA in excess of 47 mm correlated with disability [40].

#### 4.5. SRS-22

Glassman et al. showed that patients with thoracolumbar and lumbar curves tended to have a lower pain and function scores as compared to those with thoracic curves [12, 29]. The present study showed that the exercises tended to increase the SRS pain domain scores, but the pre- and post-intervention difference was not statistically significant. This might be due to the fact that most of the patients did not have marked pain at baseline. It was possible that most of the subjects had adult idiopathic scoliosis, which was not as disabling or painful as those with DLS [45].

The SRS-22 self-image ( $p = 0.001$ ) and mental health ( $p = 0.04$ ) scores, however significantly improved after the 9 months of scoliosis pattern specific exercises. The improvement in self-image is unlikely to be a result of the change of the subject's perspective [48] as the study spanned over a few months. The improvement in self-image is important as studies [48, 49] have shown that operated AIS patients and adult patients with thoracolumbar and lumbar curves had lower SRS-22 self-image scores, as compared to nonoperated group [48]. Pizones et al. found that the surgical cohort had worse SRS-22 scores in all domains with mean values under 3.1 points (range = 2.4–3.1), as compared to the conservatively treated cohort [4]. In our study, there was a significant improvement in the scores in the self-image domain. Seven subjects had scores below 3.1 points before the intervention, but after the program, only two had scores below 3.1 points. Also, the improvement of SRS-22 self-image and satisfaction scores exceeded 0.4, which is regarded as the minimal clinical important difference relating to SRS-22r (refined) in surgically treated adults with spinal deformity [50]. Improvement of the self-image may reduce the drive for surgical intervention.

#### 4.6. Clinical implications

This preliminary study showed that SBP exercises improved the Cobb angles, sagittal spinal balance, and some SRS-22 domain scores in adult patients with thoracolumbar and lumbar curves. In view of the fact that curves of ASD and DLS progress and that the present nonoperative treatments addressing adult scoliosis patients with low back pain are not effective, the authors believe it is worthwhile implementing SBP exercises in conjunction with standard medical or physiotherapeutic treatments on adult scoliosis patients with risk of progression, particularly when the patients have lumbar curves in excess of  $30^\circ$ , AVR  $\geq 33\%$ , thoracolumbar kyphosis, and positive sagittal spinal imbalance [29, 40]. A low intercrystal line is also a risk factor [6]. When the line joining both iliac crests lies below the L4/5 level, L4 is more mobile and prone to instability and translation.

#### 4.7. Limitations

The study has a number of weaknesses. The small sample size reduced the statistical power of the study. Also, the group was not homogeneous, with different degrees of degenerative changes in the lumbar spine. This would confound the outcome, as subjects with more flexible spines are expected to have better improvement. Also, it was difficult to ensure that patients followed the exercises protocol strictly at home.

Further studies are required to elucidate whether SBP positively influences the thoracolumbar and lumbar curves in adult scoliosis patients, particularly those with curves that are susceptible to progression and whether SBP when combined with the standard conservative treatments improve their effectiveness.

## 5. Conclusion

The study showed that out-patient Schroth Best Practice® exercises statistically significantly improved the Cobb angles, the sacral slope, the pelvic tilt, and SVA as well as the SRS-22 self-image and mental health domain scores in adult scoliosis patients with thoracolumbar and lumbar curves. Yet, in view of the small sample size and the weak power of the study, it is suggested that further studies be conducted to investigate whether SBP exercises are effective for the treatment of adult scoliosis patients with thoracolumbar and lumbar curves.

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## Conflict of Interest

None of the authors declare any conflict of interest.

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