

Pulmonary function changes and its influencing factors after preoperative brace treatment in patients with adolescent idiopathic scoliosis

A retrospective case–control study

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Abstract

Background: The aim of the study was to retrospectively investigate the changes in pulmonary function and its influencing factors in patients with adolescent idiopathic scoliosis (AIS) undergoing preoperative brace treatment or not.

Methods: Total 237 AIS patients (43 boys, 194 girls) who underwent operations and had a complete record of pulmonary function tests were enrolled and were divided into preoperative brace treatment group (brace treatment group, n=60) and without preoperative brace treatment group (control group, n=177). The pulmonary function parameters were compared between the 2 groups. Multiple linear regression analysis was performed to explore whether the variables, including age at operation, height, coronal Cobb's angle of main curve, number of involved vertebrae, sagittal Cobb's angle of thoracic curve, brace treatment time per day and brace treatment duration, influenced pulmonary function in the brace treatment group.

Results: No significant differences were observed in both predicted and actually measured value of forced vital capacity (FVC) and predicted value of forced expiratory volume in 1 s (FEV1) between 2 groups ($P > 0.05$), but actually measured FEV1, the percentage of actually measured and predicted value of FVC (FVC%) and FEV1 (FEV1%) were significantly lower in the brace treatment group than those in the control group ($P < 0.05$). Importantly, the above changes in actually measured FEV1 and FEV1% were obvious in AIS patients presented with a main thoracic curve ($P < 0.05$), but not in patients with a primary thoracolumbar/lumbar curve. Multiple linear regression analysis indicated that only the sagittal Cobb's angle of the thoracic curve was positively, but preoperative brace treatment duration was negatively associated with both the FVC% and FEV1% ($P < 0.05$).

Conclusion: Preoperative brace treatment may deteriorate pulmonary function in AIS patients with thoracic curve. The small sagittal Cobb angle and longer brace treatment duration may be risk factors for reduced pulmonary function.

Abbreviations: AIS = adolescent idiopathic scoliosis, FEV1% = the percentage of actually measured and predicted value of FEV1, FEV1 = forced expiratory volume in 1 s, FVC% = the percentage of actually measured and predicted value of FVC, FVC = forced vital capacity.

Keywords: adolescent idiopathic scoliosis, brace treatment, pulmonary function

1. Introduction

Scoliosis is a complex, 3-dimensional deformity characterized by a lateral spinal curvature with a Cobb's angle of 10° or more on a

standing spinal radiograph.^[1] Scoliosis can be categorized into several types based on the cause (congenital, syndromic, and idiopathic) and age (infantile, juvenile, and adolescent) of the curve development. Among them, adolescent idiopathic scoliosis (AIS) is the most common form of scoliosis where the cause is unknown and it occurs in otherwise healthy children from the age of 10 to the end of the growth.^[2] It is estimated that scoliosis affects 4% of the population worldwide, with ~85% of AIS cases. Similarly, AIS is also reported to be a frequently encountered spinal deformity in China, influencing 3% or ~0.28 billion persons <16 years of age according to the 6th national census.^[3] Other than back pain and cosmetic concerns, progressive AIS can result in thoracic cage distortion and subsequently decreases lung volume and compliance, ultimately leading to the development of restrictive lung diseases followed by cor pulmonale, which all seriously affect the quality of life of patients.^[4–7] Thus, how to arrest curve progression and minimize the deterioration in pulmonary function are important issues for spinal surgeons.

Bracing is the most commonly recommended conservative treatment for management of mild to moderate AIS.^[8–10] Bracing can mechanically modify the scoliotic spine shape and control curve progression via (1) passive mechanisms: external forces (brace pads) applied on subcutaneous skeletal structures, such as

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rib cage to form a “3-points” effect (lateral external forces on the apical vertebra and contralateral forces above and below the apical vertebra) and (2) active mechanisms: muscle control to shift the spine away from the pressure areas within the brace.^[11] In accordance with the improvement in curve progression, the study of Pehrsson et al^[12] indicated bracing also could significantly improve pulmonary function such as vital capacity ($3.8 \pm 0.7\text{L}$ vs $3.4 \pm 0.6\text{L}$, $P < 0.05$) and forced expiratory volume in 1 s (FEV1: $3.1 \pm 0.5\text{L}$ vs $2.9 \pm 0.5\text{L}$, $P < 0.05$). However, some studies reveal that wearing a brace may aggravate pulmonary function,^[12–15] which may be attributed to increased stiffness of the thoracic cage and restricted growth in the lung tissues.^[16] These studies indicate a controversial conclusion about the influence of bracing on pulmonary function and further study is needed. Importantly, most of the literatures focused on comparing the results between before and after brace,^[12,15] only the study of Yu et al^[14] aimed to observe the differences between preoperative brace treatment and without preoperative brace treatment. Nevertheless, only female AIS patients were included in the study of Yu et al.^[14]

The goal of this study was to further investigate the changes in pulmonary function in AIS patients (including females and males) with or without preoperative brace treatment. Similar to the study of Yu et al,^[14] we also explored the potential factors influencing pulmonary function in the patients undergoing brace treatment.

2. Materials and methods

2.1. Patients

This was a retrospective study of patients with scoliosis who underwent surgical interventions in the Changhai Hospital Affiliated to the Second Military Medical University between June 2001 and June 2010. The patients were selected by the first author according to the following inclusion criteria: (1) a diagnosis of AIS according to Scoliosis Research Society; (2) undergoing operations with preoperative brace treatment or not; and (3) had a complete record of demographic, preoperative radiological and pulmonary function data. The patients with other related disorders/spine anomalies were excluded. This study was approved by the Ethics Committee of Changhai Hospital and all patients provided written informed consent for the study and treatment. No registration number could be obtained due to the retrospective nature.

2.2. Treatment strategy

The spinal curve angle was measured by the same orthopedic surgeon according to Cobb's angle^[17] on anterior–posterior erect x-rays. The indications for the brace treatment were the Cobb's angles of 20° – 40° or the Cobb's angles increased by 5° annually if the initial Cobb's angles were $<20^\circ$. Milwaukee brace (cervico-thoraco-lumbo-sacral orthosis) was used if the apical vertebra was located above the T9 (Fig. 1A and B), whereas the Boston brace (thoraco-lumbo-sacral orthosis) was adopted if the apical vertebra was located under the T9 (Fig. 1C and D). When Cobb's angles still exceeded 40° after the brace treatment, the brace was removed and surgery was performed with posterior fusion and Harrington instrumentation.^[18] Surgical correction of the spine was directly performed when there was a Cobb's angle of $>45^\circ$. The co-first authors co-determined the patients to undergo which interventions.

2.3. Pulmonary function measurement

The pulmonary function was measured by the same technician preoperatively. The actual forced vital capacity (FVC) and FEV1 were measured using the portable lung function tester (Metyzer 3B system, Cortex, Germany). The predicted values of FVC and FEV1 were recorded referring to the normal value in our hospital. Then, the percentages of actually measured value and predicted value of FVC (FVC%) and FEV1 (FEV1%) were calculated.

2.4. Statistical analysis

All data were expressed as mean \pm standard deviation and analyzed by the SPSS 16.0 software (SPSS Inc., Chicago, IL). Differences in demographic, radiological and pulmonary function parameters between 2 groups were compared by Student's *t* test. Multiple linear regression analysis was performed to explore whether the demographic, radiological and brace treatment variables influenced pulmonary function (FVC% and FEV1%) in the brace treatment group. A 2-tailed *P* value < 0.05 was considered to be statistically significant. Post-hoc power analysis was calculated by the software named G*Power (version 3.1, Franz Paul, Kiel University, Kiel, Germany) to estimate the probability of detecting a statistically significant difference between groups when an actual difference does exist (that is, 1 - Type II error β). Power > 0.8 was considered as the presence of a significant difference indeed.

3. Results

A total of 237 patients (43 boys, 194 girls) were enrolled between June 2001 and June 2010 according to the inclusion criteria and they were further divided into 2 groups on the basis of whether they underwent conservative brace treatment preoperatively: brace treatment group ($n=60$, with the average daily brace treatment time of 17.2 hours [10–22 hours] and the average brace treatment time of 17.1 months [6–61 months]) and without brace treatment group (control group, $n=177$). The general characteristics of the patients in 2 groups are shown in Table 1. As a result, there were no significant differences between the above 2 groups in age of disease onset, age at operation, height, number of involved vertebrae, coronal Cobb's angle of main curve, sagittal Cobb's angle of thoracic curve (T5–T12), indicating the comparability between 2 groups ($P > 0.05$). Although predicted FVC, actually measured FVC and predicted FEV1 were not significantly changed, the FVC% (81.2 ± 14.5 vs 87.3 ± 13.5 , $P < 0.05$), actually measured FEV1 ($2.24 \pm 0.34\text{L}$ vs $2.52 \pm 0.56\text{L}$, $P < 0.05$) and FEV1% (83.4 ± 15.8 vs 92.1 ± 15.6 , $P < 0.05$) were significantly decreased in the brace treatment group compared to the control group, indicating the pulmonary function may be deteriorated by preoperative brace treatment.

In addition, according to the apex location of the main curve on the whole spinal anterior-posterior erect x-rays, patients were also classified into 2 subgroups: thoracic curve group (the apex located between the T5 and T11/12, $n=142$) and thoracolumbar/lumbar curve group (the apex located between the T12 and L5, $n=95$). As shown in Table 2, no significant differences were found in any parameters between the brace treatment group and the control group when they had thoracolumbar/lumbar curve, but for patients with thoracic curve, the actually measured FVC (2.42 ± 0.43 vs 2.72 ± 0.44 , $P < 0.05$), FEV1 (2.12 ± 0.53 vs 2.44 ± 0.35 , $P < 0.05$), and FEV1% (81.2 ± 13.4 vs 89.5 ± 17.2 , $P < 0.05$) were significantly lower in the brace treatment group than those in the control group. These findings suggest that

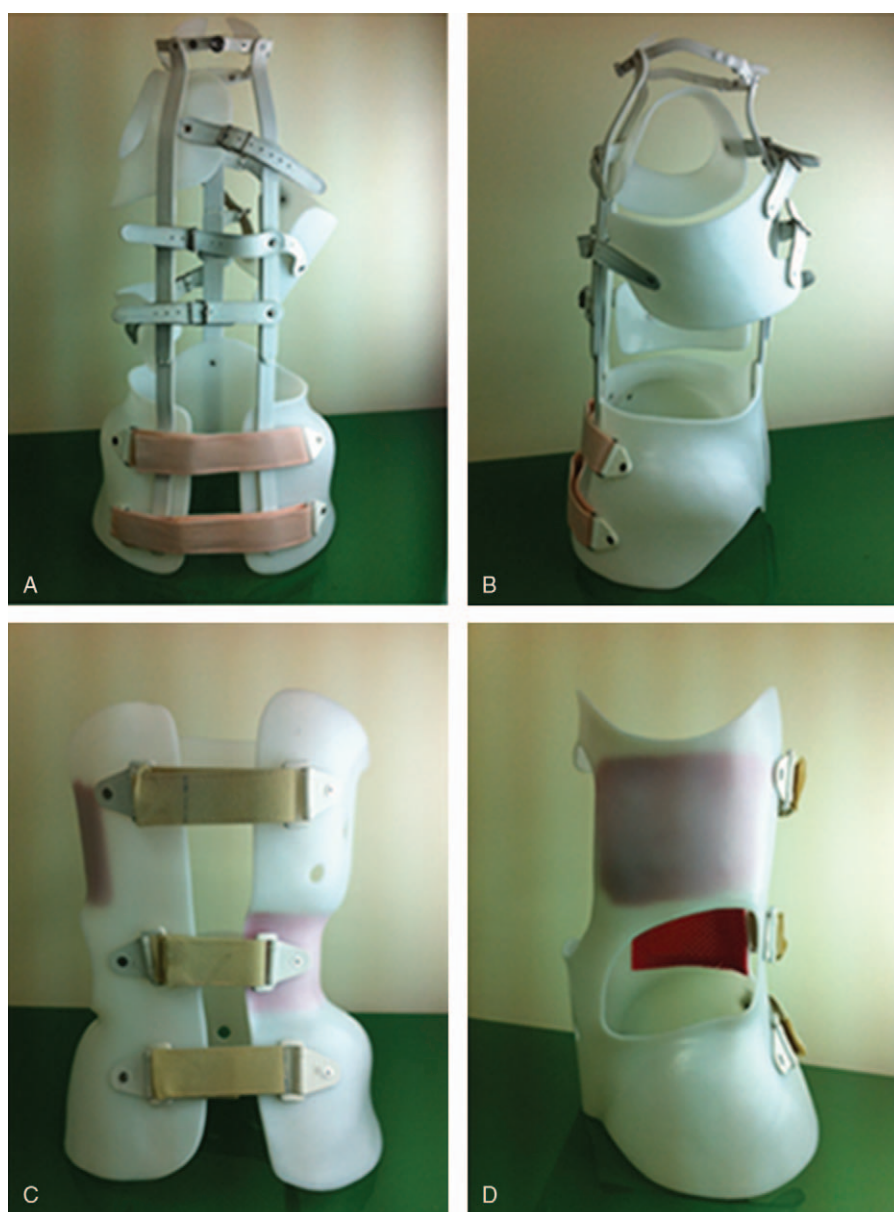


Figure 1. The Milwaukee brace and the Boston brace. A=the anteroposterior photo of Milwaukee brace; B=the lateral photo of Milwaukee brace; C=the anteroposterior photo of Boston brace; D=the lateral photo of Boston brace.

Table 1

Characteristics of the patients in the brace treatment group and control group.

Parameters	Brace treatment group (n=60)	Control group (n=177)	P	Power
Age at operation, y	13.7 ± 1.5	13.4 ± 1.5	0.1819	0.266
Age of disease onset, y	12.5 ± 1.4	12.7 ± 1.6	0.3893	0.144
Height, cm	156.7 ± 7.5	156.6 ± 6.9	0.9245	0.051
Number of involved vertebrae, n	6.4 ± 1.6	6.4 ± 1.5	> 0.99	0.050
Coronal Cobb's angle of main curve, °	53.7 ± 13	53.4 ± 12.7	0.8752	0.053
Sagittal Cobb's angle of thoracic curve, T5–T12, °	22.2 ± 14.5	23.4 ± 15	0.5897	0.084
Predicted FVC, L	3.11 ± 0.35	3.11 ± 0.34	> 0.99	0.050
Actually measured FVC, L	2.35 ± 0.55	2.34 ± 0.54	0.9019	0.052
FVC%	81.2 ± 14.5	87.3 ± 13.5	0.0033*	0.827 [†]
Predicted FEV1, L	2.56 ± 0.56	2.67 ± 0.22	0.1428	0.407
Actually measured FEV1, L	2.24 ± 0.34	2.52 ± 0.56	< 0.0001*	0.981 [†]
FEV1%	83.4 ± 15.8	92.1 ± 15.6	0.0002*	0.959 [†]

FEV1% = the actually measured value/predicted value of FEV1, FEV1 = forced expiratory volume in 1s, FVC % = the actually measured value/predicted value of FVC, FVC = forced vital capacity.

* $P < 0.01$ compared with the control group.

[†] Power > 0.8 indicates the statistical difference obtained may be conclusive.

Table 2**Characteristics of the patients in the brace treatment group and control group with thoracic curve or thoracolumbar/lumbar curve.**

Parameters	Thoracic curve				Thoracolumbar/lumbar curve			
	Brace treatment group (n=43)	Control group (n=99)	P	Power	Brace treatment group (n=34)	Control group (n=61)	P	Power
Age at operation, y	15.1±1.3	14.7±1.6	0.1509	0.320	14.5±1.3	14.2±1.7	0.3742	0.150
Age of disease onset, y	13.2±1.2	13.3±1.3	0.6672	0.072	13.3±1.5	13.4±2.1	0.7888	0.057
Height, cm	157.2±7.3	156.6±6.5	0.6272	0.076	161.2±6.3	158.8±6.9	0.0972	0.390
Coronal Cobb's angle of main curve, °	53.3±11.2	52.3±12.2	0.6464	0.075	45.2±5.4	45.7±10.2	0.7555	0.059
Sagittal Cobb's angle of t horacic curve, T5–T12, °	17.8±11.2	21.2±13.7	0.1544	0.315	37.5±17.3	35.2±17.2	0.5345	0.095
Predicted FVC, L	3.33±0.43	3.23±0.41	0.1904	0.253	3.21±0.39	3.20±0.38	0.9033	0.052
Actually measured FVC, L	2.42±0.43	2.72±0.44	0.0003*	0.963 [†]	2.77±0.61	2.77±0.57	> 0.99	0.050
FVC%	75.2±14.3	83.2±16.7	0.0710	0.799	83.3±14.5	83.2±14.8	0.9747	0.050
Predicted FEV1, L	2.79±0.42	2.69±0.33	0.1299	0.302	2.79±0.42	2.76±0.39	0.7274	0.064
Actually measured FEV1, L	2.12±0.53	2.44±0.35	0.0006*	0.972 [†]	2.63±0.53	2.64±0.49	0.9264	0.051
FEV1%	81.2±13.4	89.5±17.2	0.0056*	0.833 [†]	96.2±17.3	96.9±16.5	0.8460	0.054

FEV1% = the actually measured value/predicted value of FEV1, FEV1 = forced expiratory volume in 1s, FVC % = the actually measured value/predicted value of FVC, FVC = forced vital capacity.

* $P < 0.01$.[†] Power > 0.8 indicates the statistical difference obtained may be conclusive.

aggravated pulmonary function impairment due to brace treatment was obvious in AIS patients with thoracic curve.

Post-hoc power analysis indicated >80% power at the conventional $\alpha = 0.05$ level for detecting significant differences of the above pulmonary function parameters between the brace treatment group and the control group, further demonstrating the statistical difference above obtained may be conclusive (Table 1 and 2).

To further explore the potential factors influencing the pulmonary function, a multiple linear regression analysis was performed. In accordance with the above results, only the sagittal Cobb's angle of the thoracic curve was positively, but preoperative brace treatment duration was negatively associated with both the FVC% and FEV1% ($P < 0.05$, Table 3).

4. Discussion

Although extensive studies have demonstrated bracing is an effective therapeutic measure to prevent the progression of the deformity,^[8–10] its effect on the pulmonary function, which is concomitantly reduced in the AIS patients, remains controversial.^[14,19] This study was to further investigate the changes in pulmonary function in AIS patients undergoing preoperative brace treatment or not. In line with the results of Yu et al,^[14] we also found FVC% and FEV1% (2 crucial pulmonary function parameters, adjusted for general characteristics, such as age, sex, and height) were significantly decreased in the brace treatment group compared to the control group, demonstrating the brace treatment may further worsen the lung function. In addition, our results also indicated that the actually measured FEV1 was also lower in the brace treatment group than that in the control group,

but no significant difference was observed in the study of Yu et al.^[14] This may be attributed to the male patients to be also included in our study. It has been reported that the flexibility of primary curves is less in male AIS patients than that in females.^[20] Thus, the therapeutic effect for males may be poorer than the females,^[21] leading to the lower lung volume and FEV1 in our study. Furthermore, the smaller samples size of our study may also contribute to the difference between our study and Yu et al.^[14]

Further subgroup analysis showed that significant differences in actually measured FVC, FEV1, and FEV1% between the brace treatment group and the control group were only observed in patients with a main thoracic curve, but not in patients with a primary thoracolumbar/lumbar curve. The result was in accordance with a previous study which proved that thoracic curve has a larger impact on the difference between the percentage to the theoretical vital capacity without and with brace.^[19] These findings may result from the fact that thoracic-dominant scoliosis may more easily influence thoracic cage and cause thoracic restriction, resulting in decreased total lung capacity and subsequently FVC and FEV1.^[4]

To further confirm bracing and thoracic curve may induce pulmonary function impairment, a multiple linear regression analysis was conducted. As expected, preoperative brace treatment duration was negatively, but the sagittal Cobb's angle of the thoracic curve was positively associated with both the FVC % and FEV1%. In consideration of the harmful effect of bracing on pulmonary function,^[12–15] it is not difficult to understand the longer time of the brace wearing, more aggravated pulmonary function was present. Therefore, the duration of brace wearing should be timely adjusted according to the pulmonary function

Table 3**Multiple linear regression analysis for the risk factors of the pulmonary function in the brace treatment group.**

Parameters	Age at operation	Height	Coronal Cobb's angle of main curve	Number of involved vertebrae	Sagittal Cobb's angle of thoracic curve	Brace treatment time per day	Brace treatment duration
FVC%	-0.029	0.108	-0.059	-0.031	0.498*	-0.052	-0.259
FEV1%	0.087	0.049	-0.060	-0.078	0.455*	-0.054	-0.298*

FEV1% = the actually measured value/predicted value of forced expiratory volume in 1 s, FVC% = the actually measured value/predicted value of forced vital capacity FVC.

* $P < 0.05$.

test. It has also been reported that preoperative pulmonary function tests correlate significantly with the main thoracic curves and sagittal plane deformity severity, with kyphosis Cobb's angle $< 10^\circ$ showing significantly lower FEV1 or FVC compared to those with less deformity.^[22] Thus, it is also an important goal to restore the sagittal balance in the AIS patients. However, Fang et al^[23] found bracing did not significantly improve sagittal Cobb's angle, although increased it in some patients. Accordingly, we proposed it might not be enough to give brace treatment for a patient with smaller sagittal Cobb's angle of the thoracic curve, which seemed to be in consistent with the conclusion of Yu et al.^[14]

Although pulmonary function had been demonstrated to be deteriorated after bracing, no obvious respiratory symptoms occurred in AIS patients of our present study.^[12] This may be due to only mild pulmonary impairments in our cases evidenced by both FVC% and FEV1% of $\sim 80\%$. In addition, this result can be attributed to the small sample size of our study. These hypotheses can be partially proved by the study of Danielsson et al^[16], in which respiratory symptoms could be found in 22 of 68 patients (dyspnea in 3; wheezing in 19) undergoing braced treatment because of FVC% and FEV1% $< 60\%$ in some patients.

Our study had some limitations. Most important is its retrospective design that may result in unavoidable selection bias. Although our patients were included from June 2001 to June 2010, sample size is still limited from a single center, which may influence the statistical result. Another limitation is that only parameters of Tiffeneau index (FVC and FEV1), but not those of Motley (residual volume and total lung capacity, determined for assessment of lung hyperinflation) were used for evaluation of pulmonary function. FVC and FEV1 were chosen because they provide an adequate evaluation of the lung volume and flow functions.^[24,25] In addition, there has also been demonstrated a significant positive correlation between hyperinflation and FEV1.^[26] The decrease in FEV1 can reflect the total effects on reduction in total lung capacity, obstruction of the airways, loss of lung elastic recoil, and weakness of respiratory muscles.^[24] Thus, Motley indices were not measured in the patients of this present study. However, large-scaled, multicenter, and prospective studies with more pulmonary function parameters should be performed to further confirm the effect of bracing on pulmonary function in Chinese AIS patients.

In conclusion, our present study suggests preoperative brace treatment may deteriorate pulmonary function in AIS patients with thoracic curve. The small sagittal Cobb angle and longer brace treatment duration may be risk factors for reduced pulmonary function.

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