Pediatric Pulmonology 35:83–86 (2003)

Effects of Bracing on Lung Function in Idiopathic Juvenile Kyphosis

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Summary. Although considerable information is available on the effects of bracing on lung function in kyphoscoliosis, there is a paucity of data on idiopathic juvenile kyphosis (IJK). The present study was designed to investigate the immediate effect of bracing on lung function in children and adolescents with mild-to-moderate IJK. Spirometry, measurement of lung volumes, and arterial oxyhemoglobin saturation (SaO_2) were performed in 24 patients, 9–17 years of age, who were treated with a corrective brace for mild-to-moderate IJK (Cobb angle, 46–75°). Children were studied when braced and unbraced.

When children were unbraced, mean percent predicted values (±standard deviation) for total lung capacity (TLC), vital capacity (VC), functional residual capacity (FRC), and forced expiratory volume in 1 sec (FEV_1) were 100.0% (±13.0%), 92.7% (±14.2%), 108.2% (±20.4%), and 95.0% (±16.3%), respectively. With the brace on, significant reductions occurred in all lung function measurements: TLC decreased by 9.5% ($P < 0.001$), VC by 9.3% ($P = 0.001$), FRC by 14.2% ($P = 0.005$), and FEV_1 by 8.9% ($P = 0.009$). SaO_2 decreased from 96.2% (±1.6%) to 95.2% (±1.4%) ($P = 0.027$). An inverse relationship was observed between pre- and postbracing change in TLC and Cobb angle children ($P = 0.021$).

Our findings indicate that corrective bracing in mild-to-moderate IJK results in mild lung restriction and a clinically insignificant drop in SaO_2. The effect of bracing on TLC decreases as the severity of kyphosis increases in these patients. **Pediatr Pulmonol. 2003; 35:83–86.**

Key words: idiopathic juvenile kyphosis; brace; lung function; total lung capacity; vital capacity; functional residual capacity; forced vital capacity in 1 sec; arterial oxyhemoglobin saturation.

INTRODUCTION

Kyphosis is an exaggeration of the normal thoracic curvature that ranges from 20–45° by the Cobb measurement.[1–3] Idiopathic juvenile kyphosis (IJK) is characterized by vertebral body wedging of unknown etiology. IJK occurs in 0.4–8.0% of the general population, and constitutes the most common cause of kyphosis and the second most common cause of back pain among children and adolescents.[1] Long-term follow-up of patients with IJK suggests that, although these patients may have some functional limitations, they do not suffer major interference with their life, and their pulmonary function (unless severely kyphotic) remains in the normal range.[1,4]

The treatment of IJK is primarily nonoperative, and adolescents with mild to moderate deformity (Cobb angle less than 50–60°) can be managed with periodic radiographic follow-up. Indications for treatment remain highly debatable, as the natural history of the disease has not been well-defined.[1,4] Corrective bracing appears to be effective when instituted early in the course of the disease.[1] Surgical treatment is reserved for severe kyphosis (Cobb angle >75%) when there is curve progression, refractory pain, or neurologic insult.[1]

Although a considerable number of studies have addressed the effect of kyphoscoliosis on lung function,[5–12] there is a paucity of information on the effect of corrective bracing on lung function in patients with IJK.

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Received 29 April 2002; Accepted 16 August 2002.

DOI 10.1002/ppul.10220
Published online in Wiley InterScience (www.interscience.wiley.com).

The present study was designed to investigate the association between the severity of kyphosis and the immediate effect of an underarm corrective brace on pulmonary function in adolescents with mild to moderate IJK.

MATERIALS AND METHODS

Patients

Children consecutively diagnosed with mild to moderate IJK (Cobb angle 46–75°) who were treated with an underarm corrective brace (Penteli brace) and were able to perform pulmonary function tests were recruited from the Orthopedic Outpatient Clinic of Penteli Children's Hospital (Athens, Greece). The diagnosis was made by clinical examination and was confirmed by radiography.[1] Patients with any appreciable accompanying scoliosis (Cobb angle $\geq 10^{\circ}$), other chest deformities, muscle weakness, cardiovascular disease, evidence of acute or chronic lung disease, and smoking history were excluded from the study. The study was approved by the Ethics Committee of Panteli Children's Hospital, and written parental consent was obtained.

On the day of the study visit, all patients were assessed by complete history and physical examination by an orthopedic surgeon and a pediatric respiratory physician. Spirometry, lung volumes, and oxygen saturation (SaO_2) were performed initially with the brace off and subsequently with the brace on in the Respiratory Laboratory of Penteli Children's Hospital. Children relaxed in each state (unbraced and braced) for a period of at least 30 min. Nondeformed height was estimated from arm-span measurement.[13] All spirometric volumes were corrected to gas at body temperature and pressure and saturated with water vapor (BTPS). The study protocol was approved by the hospital Ethics Committee, and all patients and their parents gave written informed consent before entering the study.

Equipment

The Penteli underarm corrective brace consists of: 1) the pelvic girdle, manufactured from thermoplastic material similar to that of the Boston brace, and 2) the superstructure, i.e., a frame with a vertical duraluminium bar in front, which ends at a small heart-shaped pad at the level of the manumbrium and two vertical duraluminium bars in the back that bear the dorsal pads and reach the apex of the kyphos. This arrangement leaves a large area of the chest surface uncovered, and makes the brace comfortable during the warm months of the year (Fig. 1).

Spirometry was performed in the standing position, and lung volumes were measured in the upright sitting position by the closed-circuit helium dilution method (Volugraph 2000 IBM, Mijnhart). SaO_2 was recorded for at least a 2-min period by a hemoglobin saturation monitor (Oxyshuttle 2, Critikon), and the value of the stabilized reading was used in the analysis.

Statistical Analysis

Data are expressed as mean ± standard deviation (SD). The paired *t*-test was used to compare pulmonary function measurements with the brace off and on, and multiple regression analysis was used to evaluate any correlation between severity of kyphosis, duration of and patient

ABBREVIATIONS

BTPS	Gas at body temperature and pressure and saturated with water vapor
FEV_1	Forced expiratory volume in 1 sec
FRC	Functional residual capacity
FVC	Forced vital capacity
IJK	Idiopathic juvenile kyphosis
RV	Residual volume
SaO_2	Arterial oxyhemoglobin saturation
TLC	Total lung capacity
VC	Vital capacity

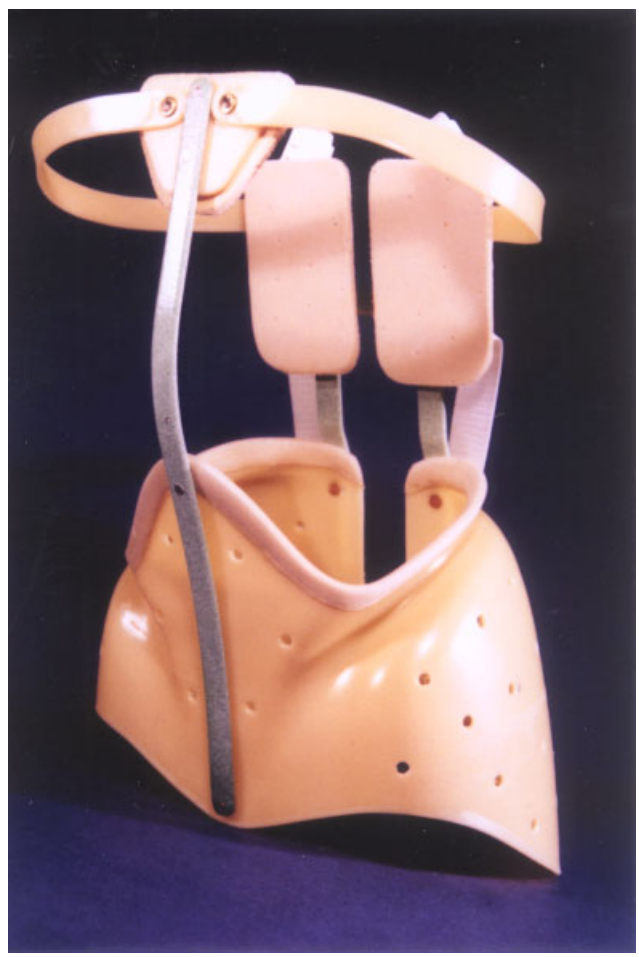

Fig. 1. Penteli underarm corrective brace (left anterior-lateral view).

adherence to the brace treatment, and the effect of the brace on pulmonary function indices.

RESULTS

Twenty-five patients (21 males) were found eligible and were recruited into the study. A 12-year-old female could not perform pulmonary function testing reliably. Anthropometrical data of the 24 patients who completed the study were as follows: age, 14.5 ± 2.1 years (range, 9–17 years); weight, 57.1 ± 14.2 kg (range, 26–70 kg); arm span, 166.7 ± 14.3 cm (range, 133–181 cm); and Cobb angle, $58.8 \pm 10.6^{\circ}$ (range, 46–75°). The number of involved vertebrae ranged from 8 –11 for the thoracic curves in 19 patients (apical vertebra T7–T10), and from 2–3 for the thoracolumbar curves in 5 patients (apical vertebra T12–L2). The duration of brace treatment ranged from 1–30 months. Reported compliance with the recommended use of the brace ranged from 50–100% (median, 65%). All patients were on a concomitant exercise program to improve flexibility. None complained of pain or discomfort while performing the pulmonary function maneuvers.

Mean values for total lung capacity (TLC), vital capacity (VC), functional residual capacity (FRC), forced expiratory volume in 1 sec (FEV_1), and SaO_2 were within normal range both with the brace on and off, although all indices decreased significantly when the patients were measured with the brace on (Table 1). Four older male patients (aged 15–17 years) had VC below 80% predicted (range, 64–76%) and FRC above 120% predicted (range, 126–138%) when unbraced. When braced, three of these patients had SaO_2 that ranged from 92–93%. The FEV_1/FVC ratio was 0.86 ± 0.08 with the brace off, and did not change significantly after bracing (0.85 ± 0.08). Multiple regression analysis revealed a significant inverse relationship between Cobb angle and decrease in TLC when patients were measured braced vs. unbraced ($P = 0.021$). No relationship was found between Cobb angle and changes in other pulmonary function measurements in braced vs. unbraced patients. There was no relationship between any of the pulmonary function measurements and the Cobb angle in braced or unbraced patients. There was also no relationship between duration of or patient adherence to the brace treatment and any of the outcome measurements.

DISCUSSION

The influence of restriction of the chest on lung function as a result of corrective bracing has not been previously described in "pure" kyphosis. In the present study, the use of a unique underarm corrective brace, the Penteli brace, resulted in a significant decrease in all pulmonary function indices measured in schoolchildren and adolescents with mild to moderate IJK.

Since all patients were measured first with the brace on, any learning effect that occurred during the procedure could only diminish the significance of the observed differences. Our results are in accordance with the effect of bracing reported in idiopathic scoliosis by most,[14–17] although not all,[18] studies. In our series, the mean reduction was 10.3% for TLC, 9.7% for VC, and 14.4% for FRC. These changes are smaller than those reported by Kennedy et al.[14] in patients with mild idiopathic scoliosis treated with either the Milwaukee or the Boston brace (16% for TLC and VC, and 26% for FRC). The fact that the Penteli brace (Fig. 1) leaves a large area of the chest surface uncovered may contribute to the smaller restrictive defect observed in the present study. The cause for the decrease in lung volumes when applying a corrective brace is postulated to be twofold.[14] First, the tight fit of the brace around the abdomen raises the diaphragm and displaces the abdominal contents into the chest, resulting in lower lung volumes and opposing the downward movement of the diaphragm during inspiration. Second, the brace directly restricts the lower ribcage. It is reasonable to assume that the alterations in the "apposition mechanics" cause an increase of the diaphragmatic workload.

TABLE 1— Pulmonary Function Measurements of Patients With Idiopathic Juvenile Kyphosis With an Underarm Corrective Brace Off (Unbraced) and On (Braced)[1]

	Unbraced		Braced		
Parameter	Absolute value	% predicted	Absolute value	% predicted	Statistical significance
TLC (L)	5.03 ± 1.75	100.0 ± 13.0	4.55 ± 1.67	89.7 ± 13.7	$P < 0.001$
VC (L)	3.78 ± 1.41	92.7 ± 14.2	3.43 ± 1.42	83.7 ± 15.8	$P = 0.001$
FRC (L)	2.53 ± 0.88	108.2 ± 20.4	2.17 ± 0.73	92.6 ± 19.8	$P = 0.005$
FEV_1 (L)	3.24 ± 1.18	95.0 ± 16.3	2.95 ± 1.05	86.4 ± 15.9	$P = 0.009$
RV/TLC (%)	24.8 ± 3.5		24.6 ± 3.3		$P > 0.1$
SaO_2 (%)	96.2 ± 1.59		95.2 ± 1.40		$P = 0.027$

[1]Data presented as mean ± SD. TLC, total lung capacity; VC, vital capacity; FRC, functional residual capacity; FEV_1, forced expiratory volume in 1 sec; L, liters; RV/TLC (%), percent increment of residual volume of total lung capacity; SaO_2 (%), percent arterial oxyhemoglobin saturation.

The use of corrective braces in the conservative management of mild-to-moderate IJK is well-established, despite the fact that only modest overall long-term correction of the prebrace deformity can be expected.[1] As concluded by Kearon et al.[19] in their study of factors that determine pulmonary function in idiopathic scoliosis, the relationship between skeletal deformity and pulmonary impairment is complex, and the severity of the impairment cannot be inferred in a clinically useful extent from the angle of scoliosis. As no correlation was demonstrated between Cobb angle and pulmonary function in unbraced children, our results show that this conclusion also holds true in the case of mild-to-moderate IJK.

Interestingly, we found an inverse relationship between the decrease in TLC and the severity of kyphosis in braced vs. unbraced children. This implies that the adverse effects of the brace on lung function are ameliorated as the severity of kyphosis increases. The physiological basis of this relationship is unclear. We speculate that in more severe cases, the corrective effect of the brace on the kyphotic spine and the more upright positioning of the braced chest wall result in an increase of the diaphragmatic apposition area posteriorly and an improvement in diaphragmatic mechanics. It is thus conceivable that the corrective effect of the brace compensates, at least partially, for its detrimental effects on lung function. Alternatively, our results could be interpreted as an absence of a corrective effect of bracing in more severely kyphotic patients. Since the study subjects were only mildly to moderately kyphotic, we consider the former interpretation more plausible.

When unbraced, our patients had a mean RV/TLC ratio of 24.8% that did not essentially change with the brace on. This mean value is within normal limits and is quite similar to the normal means reported by Polgar and Promadhat.[20] The FEV_1/FVC ratio did not reveal evidence of an obstructive defect. The drop in mean SaO_2 (from 96.2% to 95.2%) observed when patients were measured with the brace on is of no clinical importance. These results are in accordance with those of Kennedy et al.,[14] who found normal SaO_2 during sleep in a group of scoliotic patients most severely restricted by the brace. However, the marginally low SaO_2 observed in three kyphotic patients raises concerns about gas exchange in children exercising with their brace on. This observation deserves further study.

In conclusion, an impairment of pulmonary function can be found in a few patients with mild-to-moderate IJK; therefore, pulmonary function testing can be a useful tool in the initial evaluation of these patients. The use of an underarm brace results in reduction of lung volumes, although the inverse relationship between the change in TLC and Cobb angle points to a diminishing restrictive effect of corrective bracing when the severity of kyphosis increases.

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