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Decreased Orthotic Effectiveness in Overweight Patients with Adolescent Idiopathic Scoliosis

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Background: Many studies have demonstrated that orthotic treatment is effective for the prevention of curve progression in patients with adolescent idiopathic scoliosis. However, the effect of being overweight on the outcome of orthotic treatment has not been reported. The purpose of the present study was to determine whether orthotic treatment of adolescent idiopathic scoliosis is less successful for patients who are overweight than it is for those who are not overweight.

Methods: A ten-year multicenter retrospective review of patients in whom adolescent idiopathic scoliosis had been treated with a Boston or a custom-molded thoracolumbosacral orthosis was performed. The inclusion criteria were no previous treatment, skeletal immaturity (a Risser sign of 0, 1, or 2), a curve of 25° to 40° at the time of orthotic initiation, and follow-up to skeletal maturity. Patients were divided into two groups according to body habitus, with overweight patients defined as those with a body mass index in the eighty-fifth percentile or greater. Curve progression was compared between the two groups. Successful orthotic treatment was defined as no more than a 5° increase in the primary curve from the start of orthotic wear to skeletal maturity. Absolute curve progression to 45° or greater also was considered to be an adverse outcome.

Results: Two hundred and seventy-six consecutive patients from two institutions were analyzed, and thirty-one patients were considered to be overweight. The mean curve progression was 9.6° ± 7.3° for the patients who were overweight, compared with 3.6° ± 9.4° for those who were not overweight ($p < 0.01$). Overweight patients were 3.1 times more likely to have an unsuccessful result than those who were not overweight. Curve progression to 45° or greater occurred in fourteen (45%) of the thirty-one patients who were overweight, compared with sixty-nine (28%) of the 245 patients who were not overweight.

Conclusions: The results of the present study suggest that overweight patients with adolescent idiopathic scoliosis will have greater curve progression and less successful results following orthotic treatment than those who are not overweight. The ability of an orthosis to transmit corrective forces to the spine through the ribs and soft tissue may be compromised in overweight patients. This factor should be taken into consideration when making treatment decisions. Additional study is warranted to determine a threshold effect.

Level of Evidence: Therapeutic Level III. See Instructions to Authors for a complete description of levels of evidence.

Although it remains a controversial topic, orthotic treatment of adolescent idiopathic scoliosis is the only nonoperative method that has been shown to potentially decrease curve progression. The Milwaukee orthosis was first introduced as a nonoperative treatment for idiopathic scoliosis in 1945 and became the standard with which other designs were compared[1,2]. However, because of poor compliance, Watts et al. developed a smaller and more manageable orthosis in 1977, commonly referred to as a thoracolumbosacral orthosis or underarm orthosis[3]. Since then, many studies have demonstrated the effectiveness of using a thoracolumbosacral orthosis for the prevention of curve progression in

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patients with adolescent idiopathic scoliosis[4-7].

Orthotic management is generally indicated for skeletally immature patients (patients with a Risser sign of 0, 1, or 2) who present with a curve of 30° to 45° or for those in whom an initial curve of 25° demonstrates ≥5° of progression[2,4,6,8-12]. Regardless of their adherence to an orthotic regimen, not all patients benefit equally from orthotic management because many factors have been shown to increase the likelihood of curve progression, including measures of immaturity (such as a lower Risser sign, younger age, and premenarchal status)[4,13-16] and curve properties (such as initial magnitude[2,4,10,13,14,17], pattern[4,12-15,18-21], flexibility[14], amount of side-bending correction[8], and amount of initial correction in the orthosis[4,8,10,13,15,16,19,21-23]). In addition, orthotic management has been reported to be less successful for male patients than for female patients[13,17].

Orthoses exert their effects on the immature spine through biomechanical forces, which need to be of sufficient magnitude to create and sustain curve correction[24-28]. These forces are directed toward the ends and apices of the curve or curves. The extent of correction by an orthosis depends on many factors, such as the size, location, or thickness of the orthosis pads; the tension on the straps; the stiffness of the orthosis; and the direction, level, and duration of forces conveyed to the spine. Externally applied corrective forces will be limited by the area over which the forces are applied, the biomechanical properties of the spine and soft tissues, and the ability of the skin and soft tissues to bear correction while maintaining comfort and viability. It has been our experience that orthotic treatment is less effective for controlling the curves in patients with adolescent idiopathic scoliosis who are overweight, ultimately leading to a higher rate of surgery. We believe that the ability of an orthosis to transmit corrective forces to the spine through the ribs and soft tissue may be compromised in patients who are overweight. The effects of body habitus on the success of orthotic treatment have not been reported, to our knowledge. Therefore, the purpose of the present study was to compare the outcomes of orthotic treatment of adolescent idiopathic scoliosis in patients who were overweight with the outcomes in patients who were not overweight.

Materials and Methods

The present retrospective study included 320 patients with adolescent idiopathic scoliosis who were managed with either a Boston or custom-molded thoracolumbosacral orthosis at two large referral centers between 1991 and 2001. Patients who were managed with nighttime bending orthoses such as the Charleston or Providence orthoses were not included in this study. The inclusion criteria required the patient to be eleven years of age or older at the time of clinical onset; to have adolescent idiopathic scoliosis; to have a Risser sign[29] of 0, 1, or 2; to have a major curve between 25° and 40°; and not to have undergone prior treatment. We included all patients for whom either a Boston or custom-molded thoracolumbosacral orthosis had been prescribed and then excluded those with insufficient data, those who had a Risser sign of 3 or higher at the time of orthotic prescription, and those who had had previous treatment. In addition, only patients who were followed to skeletal maturity (as indicated by <6 mm of growth over six months, a Risser sign of 5, and a menarchal status of two years postmenarche [for female patients]) were included. Patients were asked to wear the orthosis for at least eighteen hours per day until discontinuance at Risser sign 4 or 5 or until a threshold for discussion of surgical options (a curve of ≥45°) was reached.

Information obtained from the records of each patient included gender, age, menarchal status, height, weight, Risser sign, initial curve magnitude (as determined with the Cobb method[30]), final curve magnitude, curve type and location, and number of hours per day that the patient reported wearing the orthosis at each visit until weaning began. A single investigator at each institution (E.E.E. or P.D.S.) measured all radiographs. For patients with more than one curve, the one with the largest Cobb angle was designated as the primary or major curve and was used for analysis. For patients who underwent surgery, the last curve measurement before surgery was recorded. The percentage of curve correction in the initial orthosis was recorded. Patients were assessed radiographically by the orthopaedist and the orthotist at each center (L.A.K., D.E.K., and P.D.S.) within one month after initial procurement. A posteroanterior radiograph of the entire spine was made with the patient standing while wearing the orthosis, with a source-to-film distance of 152 cm. An orthotist (D.E.K.) inspected each orthosis at the time of the first post-fitting visit. Modifications were made unless the orthotist thought that no further improvements were possible. Modifications included pad addition or adjustment, increasing relief on the concave side, making the upper trim line higher, or remaking the brace if necessary. The number of hours of orthotic wear was determined by recording the number of hours per day that each patient reported wearing the orthosis at each visit and then averaging these values over the life of orthotic wear, starting from initiation until weaning from the orthosis began.

Patients were grouped according to body habitus and percentile of body mass index. Body mass index was determined by dividing the weight in kilograms by the square of the height in meters (weight [kg]/height [m]^2). Patients in the eighty-fourth percentile or less were not considered to be overweight whereas those in the eighty-fifth percentile or greater were considered to be overweight, as is standard in the pediatric literature[31-33]. Data were obtained from standardized reference tables for children in the United States[31,32]. The formula $\log y = 0.011x - 0.177$ was used to correct for the decrease in height due to the curvature, where y is the loss in height (in centimeters) caused by a curve of magnitude x (in degrees)[34]. This correction resulted in three patients being moved from the overweight group to the not overweight group.

Statistical Methods

Correlational analysis was performed to determine which factors were independently related to curve progression. Patients who were overweight were then compared with patients who were not overweight with regard to curve progression, the rate of surgery, and the rate of orthotic success (defined as no

TABLE I Factors Related to Curve Progression*

Category	R Value†
Mean hours in brace per day	–0.265
Risser sign	–0.262
Overweight	0.203
Gender	0.151
Age when orthosis initiated	–0.118

*p < 0.05. †Pearson's product moment correlation coefficient.

TABLE II Multiple Regression Analysis of Factors Influencing Curve Progression

Category	Beta*
Mean hours in orthosis per day	–0.256
Risser sign	–0.241
Overweight	0.153
Gender	0.144

*Standard partial regression coefficient.

more than a 5° increase in the primary curve from the time of initiation to the time of discontinuation of the orthosis). Since the option for surgery was discussed with patients who had a curve of 45°, this threshold was used to determine the rate of surgery, regardless of whether or not the patient decided to have surgery. T tests for significance were performed, with the level of significance set at $p < 0.05$. Finally, multivariate analysis was conducted to investigate how the variables that were found to be significant in univariate correlational analysis were related to curve progression when entered together.

Results

Forty-four of the 320 patients had missing data and were excluded from the final analysis. Missing data included the initial in-orthosis correction (twenty-three patients), the mean time in the orthosis (eleven patients), the Risser sign (five patients), and the final curve progression (five patients). Thus, 276 patients from two institutions met the inclusion criteria. Of these, thirty-one patients (11%) were determined to be overweight. Two hundred and forty-three (88%) of the 276 patients were female. The mean age at the start of orthotic management was 12.8 ± 1.3 years (range, eleven to seventeen years), the mean number of hours in the orthosis was 14.3 ± 5.5 hours per day, the mean age at the time of weaning was 14.9 ± 1.4 years, and the mean time between the initiation of orthotic treatment and the final measurement was 2.1 ± 1.1 years. The mean initial curve magnitude was 32° ± 4.4°, and the mean progression over the course of brace treatment was 4.3° ± 9.3° (range, –20° to 47°) for the entire sample. With regard to outcome, 135 patients (49%) had a successful outcome (the curve did not progress >5°), eighty-three patients (30%) had an unsuccessful outcome (the curve progressed >5° and the final curve was ≥45°), and fifty-eight patients (21%) had an intermediate outcome (the curve progressed >5° but the final curve was <45°).

The factors that were significantly correlated ($p < 0.05$) with increased curve progression were a lower mean number of hours in the orthosis per day ($r = –0.265$), a lower Risser sign ($r = –0.262$), being overweight ($r = 0.203$), male gender ($r = 0.151$), and a younger age when orthotic treatment was initiated ($r = –0.118$) (Table I). These factors were included in a multiple regression analysis to determine their interaction on curve progression. The regression analysis showed that 18% of the curve progression could be explained by mean hours in the orthosis per day, Risser sign, being overweight, and gender ($p < 0.01$). The remaining 82% of curve progression was explained by variables that were unknown or were not included in this study. In other words, knowing the gender, overweight status, Risser sign, and the number of hours of orthosis wear increases the ability to predict the outcome for a patient by 18%. The weighting of each factor on curve progression, in decreasing order, was hours of wear, Risser sign, being overweight, and gender (Table II).

When the patients who were overweight were compared with those who were not overweight, the two groups were similar in terms of the mean hours of orthotic wear and the mean initial curve magnitude (Table III). There was a significant difference between the groups with regard to the mean age when the orthosis was started and the mean Risser sign ($p < 0.05$). The mean curve progression was 9.6° ± 7.3° for the patients who were overweight, compared with 3.6° ± 9.4° for those who were not overweight ($p < 0.01$). The mean in-orthosis correction was 26% ± 21.5% (with a mean initial curve magnitude of 33.3° and a mean in-orthosis correction to 24.7°) for the patients who were overweight, compared with 41% ± 20.1% (with a mean initial curve magnitude of 32.2°

TABLE III Patient Characteristics

	Orthotic Wear* *(hr)*	Initial Curve Magnitude* *(deg)*	Age When Orthosis Started*† *(yr)*	Risser Sign*†
Not overweight (n = 245)	14.3 ± 5.5	32.2 ± 4.3	12.9 ± 1.3	0.6 ± 0.8
Overweight (n = 31)	14.0 ± 5.6	33.3 ± 4.5	12.3 ± 1.2	0.3 ± 0.6

*The values are given as the mean and the standard deviation. †p < 0.05.

TABLE IV Comparison of Patients Who Were Overweight with Those Who Were Not Overweight

	Mean Progression*† *(deg)*	Mean Correction*† *(%)*	Success Rate†	Progression of >5°†	Progression to >45°‡
Not Overweight	3.6 ± 9.4	41 ± 20.1	52% (127 of 245)	48% (118 of 245)	28% (69 of 245)
Overweight	9.6 ± 7.3	26 ± 21.5	26% (8 of 31)	74% (23 of 31)	45% (14 of 31)

*The data are given as the mean and the standard deviation. †p < 0.01. ‡p < 0.05.

and a mean in-orthosis correction to 19.1°) for those who were not overweight ($p < 0.01$). The rate of success (as indicated by a curve that did not progress >5°) was 26% (eight of thirty-one) for the patients who were overweight, compared with 52% (127 of 245) for the patients who were not overweight ($p < 0.01$). The rate of curve progression to ≥45° was 45% (fourteen of thirty-one) for the patients who were overweight, compared with 28% (sixty-nine of 245) for the patients who were not overweight ($p < 0.05$) (Table IV). On the basis of the odds ratio, orthotic treatment was 3.1 times more likely to be unsuccessful for patients who were overweight than for those who were not overweight.

Discussion

Many studies have documented the apparent effectiveness of an orthosis in altering the natural history of curve progression in patients with adolescent idiopathic scoliosis[2,6,18,23]. However, it would be ideal to prescribe an orthosis to only those patients who would benefit. Lonstein and Winter demonstrated that patients with a Risser sign of 0 or 1 are three times more likely to experience curve progression than are patients with a Risser sign of 2 to 5 and that curves of ≥20° are three times more likely to progress than are smaller curves[2]. A prospective study conducted by the Scoliosis Research Society demonstrated that eighty-five (66%) of 129 skeletally immature female patients with untreated idiopathic curves between 25° and 35° experienced >5° of curve progression[6]. Thus, most authors agree that orthoses are indicated for skeletally immature patients (patients with a Risser sign of 0, 1, or 2) who present with a curve of 30° to 45° or for those in whom an initial curve of 25° demonstrates 5° of progression[2,4,6,8-12].

Factors that have been shown to increase the risk of curve progression in previous studies also were shown to increase the risk of curve progression in the current study, including fewer hours of orthosis wear per day[2,7,10], a lower Risser sign[2,13-15,22], and male gender[13,17]. However, being overweight also was predictive of curve progression. The effect of body habitus on the outcome of orthotic treatment has not been reported previously, to our knowledge. The results of the present study also indicate that the rate of surgery is higher for patients who are overweight than for those who are not overweight.

The reason why orthotic treatment is less successful for patients who are overweight may be that they have substantially less in-orthosis curve correction than those who are not overweight. The mean curve correction for the patients who were not overweight (41%, based on a mean initial curve magnitude of 32.2° and a mean in-orthosis correction to 19.1°) was 58% greater than the mean curve correction for patients who were overweight (26%, based on a mean initial curve magnitude of 33.3° and a mean in-orthosis correction to 24.7°). The mean curve correction for overweight patients (26%) was substantially below the values reported in previous studies that have demonstrated mean in-orthosis corrections, for all patients, in the range of 36% to 62%[3,4,8,10,13,16,21-24,35].

A successful outcome depends on the ability of an orthosis to exert forces of sufficient magnitude to create and maintain curve correction. Previous studies have documented the importance of the forces generated by the orthosis[24-28]. Chase et al. demonstrated that, in patients with similar curve types, increased force through the compression pads resulted in improved correction of the scoliotic curve[24]. Wong et al. reported that the Cobb angle was strongly correlated with both pad pressure and strap tension[27]. Overweight patients have more soft-tissue thickness and surface area through which the corrective forces of the pads and straps are transmitted. This may dissipate the forces to the spine, resulting in less curve correction.

There may be other explanations for why orthotic treatment is less effective for patients who are overweight. The orthosis may have a poorer overall fit for overweight patients, leading to shifting and discomfort. However, there was little difference in the rate of compliance reported for each group (mean, 14.0 hours for patients who were overweight compared with 14.3 hours for those who were not). Patients with increased body mass may have greater loading of the spinal column and, as a result, greater compression force on the curve. The hormonal effects associated with obesity may be a causative factor. Increasing insulin resistance and hyperinsulinemia are correlated with increasing body mass index[36-38]. Insulin resistance during puberty may increase the growth process by amplifying the effects of growth hormone and insulin-like growth factor-I[38]. Also, increased peripheral adipose tissue leads to increased estrogen levels[39], which may influence growth.

The outcome of orthotic treatment can be measured in terms of whether curve progression (usually defined as progression of >5°) is successfully halted or whether the curve reaches a set threshold at which surgery is commonly offered. In the present study, the curve was successfully halted in 135 (49%) of the 276 patients whereas it reached a surgical threshold in eighty-three (30%). These values compare well with the values in previous studies as well as with the natural history of this condition[4-6,10,13,16,18,20,22]. However, in the group of thirty-one patients who were overweight, the curve was successfully halted in only eight patients (26%) whereas it progressed to ≥45° in fourteen (45%). In the remaining nine overweight patients (29%), the curve progressed by >5° but the final magnitude was <45°, representing an intermediate outcome.

The present study had several limitations. It was not a prospective study. Several factors that have been reported to affect curve progression were not studied. The number of hours of orthotic wear was determined on the basis of self-reports and not objective measurements.

To our knowledge, the present report describes the first study in which body habitus has been found to be a predictive factor in the orthotic treatment of adolescent idiopathic scoliosis. This factor should be taken into account when making treatment decisions. Additional study is warranted, particularly to determine if there is a threshold body type for which orthotic management becomes less effective. As more and more children are becoming overweight[40], the effects of being overweight on the outcome of orthotic treatment of adolescent idiopathic scoliosis is increasingly important. ■

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