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Changes in height, weight, and body mass index after posterior spinal fusion in juvenile and adolescent idiopathic scoliosis

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Abstract

Purpose: Posterior spinal fusion for idiopathic scoliosis is known to increase spinal height, but the impacts on weight and resulting body mass index are unknown. This study assesses body mass index, weight, and height percentile changes over time after posterior spinal fusion for idiopathic scoliosis.

Methods: Body mass index, weight, and height age- and sex-adjusted percentiles for patients with idiopathic scoliosis undergoing posterior spinal fusion between January 2016 and August 2022 were calculated based on growth charts from the Centers for Disease Control for Disease Control and compared to preoperative values at 2 weeks, 3 months, 6 months, 1 year, and 2 years. The data were analyzed for normality with a Shapiro–Wilk test, and percentiles were compared with the Wilcoxon signed-rank tests.

Results: On average, 12.1 ± 2.3 levels were fused in 269 patients 14.4 ± 1.9 years, and percentiles for body mass index, weight, and height preoperatively were 55.5 ± 29.4%, 57.5 ± 28.9%, and 54.6 ± 30.4%, respectively. Body mass index and weight percentiles decreased at 2 weeks (−10.7%, $p < 0.001$; −4.6%, $p < 0.001$, respectively) and 3 months (−6.9%, $p < 0.001$; −3.2%, $p < 0.001$, respectively) postoperatively. Postoperative weight loss at 2 weeks averaged 2.25 ± 3.09% of body weight (0.98 ± 4.5 kg), normalizing by 3 months. Body mass index percentile normalized at 1 year, but height percentile was increased at 2 weeks (2.42 ± 1.72 cm, $p < 0.001$) and through 2 years.

Conclusion: Despite initial height increase due to deformity correction, acute postoperative weight and body mass index percentile decreases postoperatively normalize by 1-year body mass index percentile. Physicians may benefit from utilizing this information when discussing the postoperative course of posterior spinal fusion with idiopathic scoliosis.

Level of evidence: 4, Retrospective Case Series.

Keywords: Body mass index, adolescent idiopathic scoliosis, weight, posterior spinal fusion, scoliosis

Introduction

Idiopathic scoliosis (IS) is the most common spinal deformity in children and adolescents, with the definitive surgical treatment being posterior spinal fusion (PSF).[1,2] PSF has been shown to have long-lasting and reliable outcomes in the vast majority of patients, preventing further deformity progression and pulmonary function decline.[1,3] However, the implications regarding postoperative body mass index (BMI) percentile of pediatric patients undergoing PSF are not well understood. Two main factors likely influence postoperative changes: changes in height after deformity correction and changes in activity level.

Patient activity is decreased after PSF and return to a thletic activity is correlated with distal level of fusion, Lenke classification, and postoperative Scoliosis Research Society-22 (SRS-22) score.[4] The type of sport also impacts return timeline; a study of patients cleared to full activity

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within 4–8 weeks postoperatively found that almost half do not reach baseline sports performance by 3 months postoperatively.[5] While return to sport times vary, several sources describe full return to sports by 6–12 months.[6,7]

BMI change in scoliosis is complicated by the natural effect of scoliosis on the body leading to decreased height.[8] Furthermore, patient clinical and spinal height have been noted to increase after PSF for scoliosis, and models have been created to predict this change.[9–13] However, the long-term implications of PSF on height and BMI throughout the recovery process are not well defined.

This study seeks to describe the change in BMI percentile for age and sex, accounting for the change in height percentile, after PSF for IS. Our hypothesis was that BMI percentile would decrease in the short term after PSF due to immediate height change, but eventually return to preoperative levels.

Materials and methods

This retrospective institutional review board (IRB) approved study included all pediatric patients from a single hospital with either juvenile idiopathic scoliosis (JIS) or adolescent idiopathic scoliosis (AIS) who underwent PSF between 1 January 2016 and 31 August 2022. Exclusion criteria included prior spinal surgeries (i.e. growing rods) and nonidiopathic spinal deformity such as congenital, syndromic, or neuromuscular scoliosis. Demographic data including age at fusion surgery, race, sex, type of scoliosis (AIS or JIS), location of major curve (thoracic vs lumbar), height, weight, BMI, the Risser stage, and total levels instrumented were recorded from the surgical visit. Subsequent clinic follow-up visits were reviewed for patient height, weight, and BMI. Time from surgery was utilized to categorize each visit into one of five categories: 2 weeks (visit within 42 days of surgery), 3 months (visit between 42 and 120 days), 6 months (visit between 120 and 270 days), 1 year (visit between 270 and 548 days), and 2 years (visit between 548 and 1096 days). Current practice at our institution is to clear for light activities including biking, light jogging, and light strength training at 6 weeks and return to sport at 12 weeks with no restrictions.

If patients required other surgeries after their PSF for unrelated reasons (e.g. anterior cruciate ligament (ACL) reconstruction, open reduction internal fixation of tibia fracture, cubital tunnel release, appendectomy, etc.), then their most recent follow-up before subsequent surgery was the last follow-up included for analysis.

Height, weight, and BMI percentiles adjusted for age and sex were calculated for each time point utilizing the Centers for Disease Control and Prevention (CDC) calculators to account for changes related to normal growth and development. Patients were categorized into BMI percentile classifications of underweight (less than 5th percentile), normal weight (between 5th and 85th percentile), overweight (between 85th and 95th percentile), and obese (greater than 95th percentile).[14]

Data distribution was analyzed for normality using a Shapiro–Wilk test of normality. Differences in height, weight, and BMI percentile changes were compared between preoperative visit and all postop visits using nonparametric Wilcoxon signed-rank tests. Patients were then stratified by groups (BMI classification, sex, IS type, and curve location), and each of the respective stratified groups were compared using the Kruskall–Wallis tests assessing BMI percentile change at each respective time point with post hoc analysis via pairwise comparisons. To account for similarly low BMI percentiles at two time points masking weight change in the underweight population, paired samples *t*-tests compared patient weight at time points until normalization to preoperative values. Finally, patients were stratified based on the Risser stage at surgery (0 or 1, 2 or 3, and 4 or 5) and paired *t*-tests compared BMI percentile at each follow-up compared to preoperative values.

Results

Two hundred and sixty-nine patients met inclusion criteria (Figure 1).

Average age at time of surgery was 14.4 ± 1.9 years, and 79.9% of patients were female with an average of 12.1 ± 2.3 levels fused. A total of 173 (64.3%), 90 (33.5%), and 6 (2.2%) patients had thoracic, thoracolumbar, and lumbar curves, respectively. A total of 42 patients (15.6%) had JIS and 226 patients (84.0%) had AIS. Preoperatively, 12 (4.5%) were underweight, 197 (73.2%) were normal weight, 41 (15.2%) were overweight, and 19 (7.1%) were obese. On average, percentiles for BMI, weight, and height preoperatively were $55.5 \pm 29.4\%$, $57.5 \pm 28.9\%$, and $54.6 \pm 30.4\%$, respectively (Table 1).

Height percentile significantly increased at all time points, with the greatest increase being, on average, 8.2% at the 2-week visit ($p < 0.001$) or 2.42 ± 1.72 cm. Height percentile also increased significantly at the 3-month (mean = 7.3%, $p < 0.001$), 6-month (mean = 6.1%, $p < 0.001$), 1-year (mean = 4.7%, $p < 0.001$), and 2-year follow-up visits (mean = 3.5%, $p < 0.001$) (Table 2 and Figure 2). Weight percentile significantly decreased at the first two time points, with the greatest decrease being, on average, 4.6 percentile points ($p < 0.001$) at 2 weeks. Weight percentile decreased 3.2 percentile points at the 3-month point ($p < 0.001$). Actual postsurgical weight loss averaged $2.25 \pm 3.09\%$ of preoperative body weight at 2 weeks (0.98 ± 4.5 kg) and normalized back to baseline by 3 months postoperatively ($0.05 \pm 4.3\%$ of preoperative body weight).

BMI percentile significantly decreased at the 2-week (mean = −10.7%, $p < 0.001$), 3-month (mean = −6.9%, $p < 0.001$), and 6-month (mean = −3.9%, $p < 0.001$)

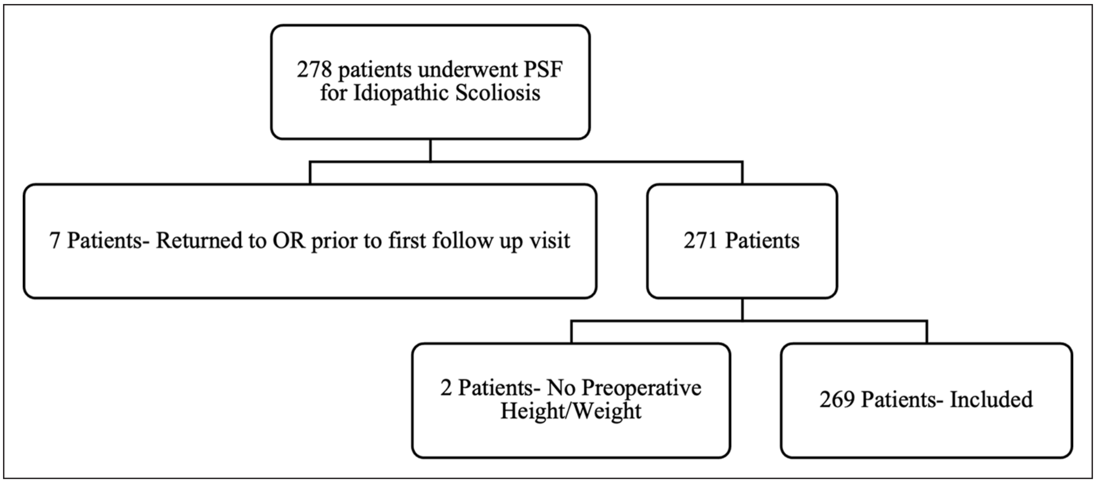

Figure 1. Methodology for patient inclusion/exclusion.
PSF: posterior spinal fusion; OR: operating room.

Table 1. Patient demographics and characteristics at time of surgery.

	Patients ($n=269$)
Age, years ±SD	14.4 ± 1.9 years
BMI percentile, ±SD	55.5 ± 29.4%
Height percentile, ±SD	54.6 ± 30.4%
Weight percentile, ±SD	57.5 ± 28.9%
Sex, *n* (%)	
Male	54 (20.1%)
Female	215 (79.9%)
Initial BMI percentile, *n* (%)	
Underweight	12 (4.5%)
Normal BMI	197 (73.2%)
Overweight	41 (15.2%)
Obese	19 (7.1%)
Race, *n* (%)	
Asian/Pacific Islander	14 (5.2%)
Black/African American	27 (16.0%)
White	173 (64.3%)
Other/none specified	55 (20.4%)
Diagnosis, *n* (%)	
JIS	42 (15.6%)
AIS	226 (84.0%)
Number of levels fused, ±SD	12.1 ± 2.3
Risser stage, *n* (%)	
0 or 1	74 (27.5%)
2 or 3	57 (21.2%)
4 or 5	138 (51.3%)

BMI: body mass index; JIS: juvenile idiopathic scoliosis; AIS: adolescent idiopathic scoliosis; SD: standard deviation.

follow-ups compared to BMI percentile preoperatively. At 1 and 2 years, the difference in BMI percentile was not significantly different from the BMI percentile preoperatively (mean = −2.2%, $p=0.106$ and mean = −2.0%, $p=0.260$, respectively) (Table 2 and Figure 2). There was no significant difference between male and female patients in change in BMI percentile at any of the follow-up time points ($p=0.160$–0.906). However, females had a higher BMI percentile preoperatively than males (58.7% vs 42.9%, $p=0.001$). Curve location (thoracic, thoracolumbar, lumbar) was not a significant predictor in a patient's change in BMI percentile at any follow-up time point ($p=0.09$–0.83). BMI percentile preoperatively was significantly higher in JIS compared with AIS (66.8% vs 53.4%, $p=0.008$), but there was no significant difference between the changes in either group from surgery ($p=0.106$–0.869).

When stratified by the Risser stage, patients with Risser 0 or 1 only demonstrated decreases in BMI percentile at the 2 weeks and 3 months postoperatively ($p<0.001$). Patients with the Risser stage 2 or 3 experienced significant decreases in BMI percentile at 2 weeks ($p<0.001$), 3 months ($p<0.001$), and 6 months ($p=0.002$) postoperatively, but normalized by 1 year. The group of patients at the Risser stage 4 or 5 experienced significant decreases in BMI percentile at all time points: 2 weeks ($p<0.001$), 3 months ($p<0.001$), 6 months ($p=0.003$), 1 year ($p=0.033$), and 2 years ($p=0.029$).

When comparing patients based on BMI percentile classification (underweight, normal weight, overweight, and obese) significant differences were observed. Patients who were normal weight preoperatively experienced a greater drop in BMI percentile at 2 weeks and 3 months postoperatively compared with every other group ($p<0.006$) (Table 3). To assess weight changes in the underweight group with more sensitivity, actual weight loss was compared at 2 weeks and 3 months. The average weight loss at 2 weeks was 0.7 ± 0.9 kg ($p=0.02$), but weight normalized at 3 months ($p=0.532$).

Table 2. Change in BMI and height percentile at different postoperative time points after posterior spinal fusion.

Visit time point	Mean BMI percentile change from surgery	*p*-value for BMI change	Mean height percentile change from surgery	*p*-value for height change	Mean weight percentile change from surgery	*p*-value for weight change
Surgery	0	N/A	0	N/A	0	N/A
2 Weeks, *N* = 231	−10.7 ± 10.1%	<0.001*	8.2 ± 8.2%	<0.001*	−4.6 ± 7.7%	<0.001*
3 Months, *N* = 226	−6.9 ± 9.2%	<0.001*	7.3 ± 8.1%	<0.001*	−3.2 ± 10.6%	<0.001*
6 Months, *N* = 175	−3.9 ± 11.7%	<0.001*	6.1 ± 8.6%	<0.001*	0.0 ± 8.8%	0.656
1 Year, *N* = 148	−2.2 ± 12.6%	0.106	4.7 ± 9.4%	<0.001*	0.8 ± 11.1%	0.096
2 Year, *N* = 100	−2.0 ± 13.7%	0.260	3.5 ± 10.8%	<0.001*	0.7 ± 12.8%	0.611

BMI: body mass index; N/A: not applicable.
*Indicates statistical significance.

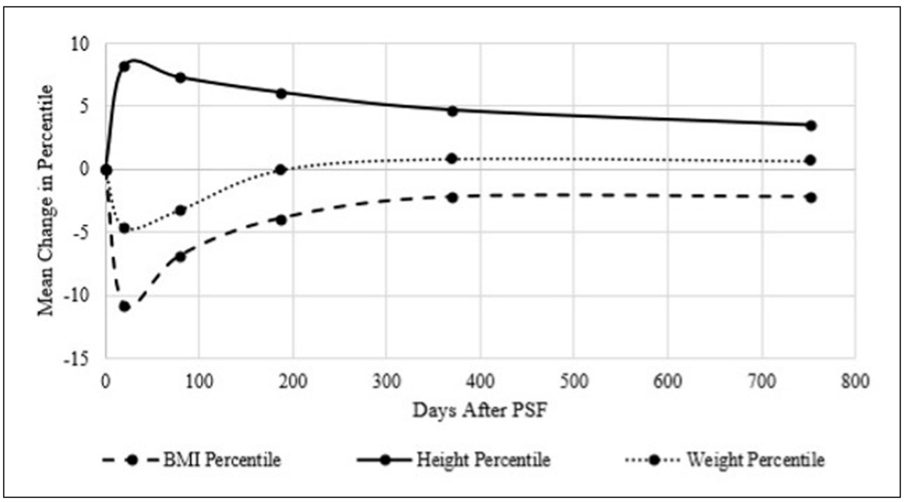

Figure 2. Change in height, weight, and BMI percentile after posterior spinal fusion.
BMI: body mass index; IS: idiopathic scoliosis.
*Statistically significant difference from preop ($p < 0.05$).

Table 3. Postoperative change in BMI based on preoperative BMI classification.

Time point	Mean BMI difference from surgery (number of patients)				*p*-value
	Underweight	Normal weight	Overweight	Obese	
2 Weeks	−1.2 ± 1.1% (12)	−13.6 ± 10.1% (168)	−4.9 ± 5.5% (36)	−0.68 ± 1.0% (15)	<0.001*
3 Months	−0.1 ± 2.3% (8)	−8.6 ± 9.9% (168)	−2.6 ± 4.0% (34)	−0.9 ± 1.4% (16)	<0.001*
6 Months	−0.3 ± 2.7% (8)	−4.9 ± 13.1% (130)	−1.29 ± 5.4% (25)	−0.1 ± 0.8% (12)	0.309
1 Year	1.6 ± 2.8% (3)	−2.8 ± 14.0% (111)	−1.4 ± 9.3% (22)	0.3 ± 0.8% (12)	0.611
2 Years	−4.1 ± 10.5% (5)	−2.2 ± 15.3% (77)	−2.8 ± 6.7% (12)	0.6 ± 1.2% (6)	0.870

BMI: body mass index.
*Indicates statistical significance.

Discussion

The increasing prevalence of childhood obesity demands further research and understanding of the factors that contribute to BMI across all disciplines of medicine.[15,16] PSF is a major surgery, and patient activity is limited afterwards. However, exclusively studying BMI ignores the impact of PSF on height, which is a confounding variable. This study found that despite initial BMI percentile decreases secondary to height gain and acute postoperative weight loss, patient BMI percentile returns to preoperative levels by 1 year postoperatively. Patients with normal weight are subject to the largest BMI percentile change up to 3 months postoperatively, with an average drop of 13.6 percentile points at 2 weeks and 8.6 percentile points at 3 months.

BMI change after surgery has also been studied in the pediatric population of patients undergoing ACL reconstruction, with findings demonstrating an increase in BMI at 1 year postoperatively.[15–18] However, the studies on BMI changes after ACL reconstruction in adolescent patients do not need to account for any surgical impact on patient height. In this analysis, it is noteworthy that the height percentile increase is maximal at the 2 weeks visit and lower for each time point after 2 weeks. Future research is warranted into evaluating the long-term height changes and implications of total height growth/velocity of patients fused based on age at time of PSF.

A previous study on weight percentile changes as a proxy for nutritional status among patients with neuromuscular scoliosis being treated with PSF found patients under the 50th weight percentile preoperatively gained weight, a change stable up through 5 years. However, patients over the 50th weight percentiles did not notice any significant change in their weight percentile.[19] Our results demonstrate that underweight patients with IS are not subjected to a decrease in their BMI percentile up through 2 years postoperatively.

Weight percentile was significantly decreased at 2 weeks and 3 months, and therefore, the precipitous drop in BMI percentile is due to an increase in height percentile coupled with a decrease in weight percentile. Actual weight loss averaged 2.25% of preoperative bodyweight, 1 kg, at 2 weeks. The increase in height from scoliosis surgery appears to drive the initial decrease in BMI percentile around the 6-month time point. However, at 1 and 2 years postoperatively, patient height percentile remains increased, while patient BMI restores to preoperative range around 1 year postoperatively. The majority of patients in this analysis were of normal weight classification preoperatively, and these patients had the largest drop in BMI postoperatively. The weight changes between the different preoperative BMI classifications were significantly different at 2 weeks and 3 months. Similar findings were found in the population of patients undergoing ACL reconstruction.[17,18] The results of this study suggest that underweight patients do not appear to be at a higher risk of BMI percentile drop or loss of absolute weight than normal weight patients and overweight and obese patients should not be expected to correct more to normal weight BMI percentile from PSF. However, it is important to note that utilizing BMI percentile limits sensitivity to BMI change at extreme values in which BMI may change, but a patient remains at a similar percentile relative to others.[20] At 2 years, there was no significant difference between the change in BMI percentile between the different preoperative classifications. Analyzing BMI percentile change based on the Risser stage demonstrates that patients with less growth remaining appear more at risk of a drop in BMI percentile at 2 years postoperatively.

Some limitations to this study should be noted, including its retrospective nature. Of the 269 patients, only 55 patients had consistent follow-up with height and weight measured at every time point evaluated. BMI has its flaws as a metric, but there is some utility to assessing patient weight to height ratio and tracking the change in BMI percentile via sex and growth-related changes accounts for some confounding variables.[15,16,20] However, the best method for assessing BMI change over time is subject to debate. An analysis of six different BMI methods (BMI, BMI *z*-score accounting for sex and age (BMIz), extended BMIz to decompress *z*-scores above the 95%,[21] percent of the 50th percentile on an arithmetic or logarithmic scale, and percent of the 95th percentile) found short-term variability within BMI and BMI adjusted for sex and age metrics (BMIz).[20] BMI controlled for sex and age with the CDC growth charts as used in this analysis (BMIz) was found to be biased for extremely obese patients and variable within 1 year. However, this limitation is minor because there were only 15 obese patients of 269 in this study, and this study followed patients up to 2 years. Another limitation includes our inability to include specific information for patients regarding what activities and sports they were involved with preoperatively and how their involvement changed following PSF. Finally, changes in activity can also be due to patients transitioning from adolescence into young-adult hood, during which a transition to college may lead to natural change in physical activity or sports participation levels.

In conclusion, this study illustrates the postoperative changes in patient height, weight, and BMI percentiles following PSF in patients with AIS and JIS. An acute decrease in BMI percentile following surgery, secondary to increased spine height and decreased weight, should be expected. However, by 1 year postoperatively, there was no statistical difference in BMI percentile compared to patient's preoperative BMI percentile.

Author contributions

All authors meet the requirements for authorship and the author list and contributions are as follows. In addition to the below tasks, all authors gave final approval of the version we are submitting:

Mitchell A Johnson, MD: study design, data acquisition, statistical analysis, and primary manuscript drafting.

Peter M Cirrincione, BA: data acquisition, statistical analysis, and manuscript drafting.

Colson P Zucker, BA: data acquisition, statistical analysis, and manuscript drafting.

John S Blanco: development of research aims, study guidance, data interpretation, and final manuscript editing.

Roger F Widmann: data interpretation, development of research aims, study guidance, and final manuscript editing.

Jessica H Heyer: development of research aims, study design, study guidance, data interpretation, and final manuscript editing.

This work has been submitted and accepted for presentation at an international conference but has not been submitted elsewhere or previously published in part or in whole as a manuscript.

Compliance with ethical standards

Roger F. Widmann, MD is on the International Editorial Board of the Journal of Children's Orthopaedics. This study was performed retrospectively with institutional review board (IRB) approval for exemption of expressed informed consent from included patients.

Declaration of conflicting interests

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