# High Risk of Mismatch Between Sanders and Risser Staging in Adolescent Idiopathic Scoliosis: Are We Guiding Treatment Using the Wrong Classification?

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**Background:** Despite known limitations, Risser staging has traditionally been the primary marker of skeletal maturity utilized in decision-making for treatment of adolescent idiopathic scoliosis (AIS). The purpose of this study is to assess the incidence and factors associated with mismatch between Risser Staging and Sanders classification, and determine interobserver reliability.

**Methods:** We reviewed the medical records of consecutive patients aged 10 to 18 referred to our institution for evaluation of AIS from January to June 2016 with a closed triradiate cartilage. Data collected included sex, age, race, height, weight, body mass index percentile, menarchal status, Risser stage, Sanders classification, and major curve. Risser and Sanders stage was determined by 2 fellowship-trained pediatric spine surgeons and 1 pediatric orthopaedic nurse practitioner. Mismatch was defined as Risser stage 2 to 4 corresponding to Sanders 3 to 5, and Risser 0 to 1 corresponding to Sanders 6 to 7.

**Results:** A total of 165 consecutive patients were identified (mean age: 13.9 ± 1.7 y, major curve 28.2 ± 15.4 degrees, 76% female). The risk of skeletal maturity mismatch, based on the criteria of Risser 2 to 5 (limited growth remaining) corresponding to Sanders 3 to 5 (significant growth remaining) was 21.8%, indicating that 1 of 5 patients would be undertreated if managed by Risser criteria. Conversely, the mismatch risk for Risser 0 to 1 corresponding to Sanders 6 to 7 was 3.6%, leading such patients to be treated conservatively longer than necessary. Males and those of Hispanic ethnicity were at a higher risk of mismatch (23.1% vs. 11.9%, $P = 0.08$; 33.3% vs. 8.8%, $P = 0.04$, respectively). Body mass index percentile, race, and major curve were not associated with mismatch. The unweighted and weighted interobserver κ for Risser staging was 0.74 and 0.82, respectively, and 0.86 and 0.91 for Sanders classification, respectively.

**Conclusion:** Given the limited sensitivity of Risser staging during peak growth velocity, high mismatch risk, and lower interobserver reliability, the Sanders classification should be utilized to guide treatment options in patients with AIS. Compared with Sanders, utilizing Risser staging results in mistreatment in a total of 1 of 4 patients, with the vast majority being undertreated.

**Level of Evidence:** Level II.

**Key Words:** adolescent idiopathic scoliosis, Risser stage, Sanders classification, skeletal maturity, conservative treatment

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The progression of adolescent idiopathic scoliosis (AIS) correlates with multiple patient characteristics, including rate of skeletal growth, age of menarche, curve type, Risser classification, and Sanders stage.[1–4] Estimating skeletal maturity plays a critical role in guiding treatment options for patients with AIS, as deformity may rapidly progress during peak growth periods. Informed patient counseling regarding the risk of curve progression, conservative treatment such as bracing, and elective surgery hinges upon accurately identifying the patient's skeletal maturity.[1,5,6]

In 1958, Risser[7] introduced a method to assess skeletal maturity based on the extent of ossification in the left iliac apophysis. Within this system, patients can progress from stage I, which corresponds to ossification of under 25% of the iliac crest, to stage V, or complete ossification and fusion, within a period of 1 to 3 years. However, during the acceleration phase of puberty, the iliac crest remains nonossified, allowing the patient to linger in Risser stage 0 throughout this crucial period. Therefore, Risser stage 0 usually encompasses a wide age range in skeletally immature patients,[8] and may subsequently be misleading for guiding treatment.[9,10] These deficiencies led Sanders and colleagues to develop a new method, derived from the Tanner-Whitehouse 3 approach, which utilized the degree of ossification of the physes in both the metacarpals and phalanges as a marker for skeletal maturity.

Accordingly, the Sanders classification is able to further stratify patients who are at or near peak growth

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velocity,[9] which provides a better guide to risk of progression and thus treatment options.[9] The purpose of this study is to determine the risk of skeletal maturity mismatch between the Risser classification and Sanders stage in patients with AIS undergoing conservative treatment, and to determine interobserver reliability. In other words, how often does Risser classification significantly under (or over) estimate growth remaining which can lead to under (or over) treatment?

## METHODS

### Study Design

This is a retrospective comparative study.

### Setting

Patients were identified from a single tertiary academic medical center.

### Participants

Patients diagnosed with AIS, between the ages of 10 and 18 years, who were evaluated in an outpatient orthopaedic clinic from January to July 2016 were enrolled. Patients with open triradiate cartilage, non-idiopathic scoliosis, prior spine or hip surgery, endocrine disorders, or any underlying diagnosis or chronic illness that could potentially affect growth or skeletal maturity were excluded. In addition, patients who did not complete both the Risser stage and Sanders classification radiograph within a 6-week time-period were excluded.

### Data Collection

Clinical charts and radiographic images were reviewed to determine age, sex, race, ethnicity, medical comorbidities, major coronal curve (Cobb angle), height, weight, body mass index (BMI) percentile, and menarchal status in females.

Risser stage and Sanders classification were determined by 2 fellowship-trained pediatric spine surgeons and 1 pediatric orthopaedic nurse practitioner, each of whom had more than 10 years of specialized experience.

### Outcome

Mismatch was defined as Risser stage 2 to 4 (relatively mature skeletally) corresponding to Sanders 3 to 5 (relatively immature skeletally), and Risser 0 to 1 (relatively immature skeletally) corresponding to Sanders 6 to 7 (relatively mature skeletally). In addition, data were reassessed by evaluating the mismatch criteria of Risser stage 2 to 4 corresponding to Sanders 2 to 4 to determine the proportion of patients with rapid growth remaining who looked to be well past their rapid growth based on their pelvic markers (Table 1). Although it is acknowledged that Sanders 6 may correspond to Risser 1, Sanders 6 represents the stage at which clinicians consider cessation of conservative treatment. This is in contrast to Risser 0 and 1, which are consistently grouped together, as they indicate a lack of skeletal maturity.

**TABLE 1.** Patient Characteristics

| Characteristics | Mean (±SD) |
|---|---|
| Age (y) | 13.9 ± 1.7 |
| Sex (female) (%) | 76 |
| Race (%) | |
| White | 81 |
| African American | 8 |
| Asian | 9 |
| Other | 2 |
| Ethnicity (%) | |
| Non-Hispanic | 85 |
| Hispanic | 15 |
| Major curve (deg.) | 28.2 ± 15.4 |
| Height (cm) | 161.3 ± 10.2 |
| Weight (kg) | 52.0 ± 11.5 |
| BMI | 20.0 ± 3.3 |
| BMI percentile | 42.8 ± 32.0 |

BMI indicates body mass index.

### Power and Statistical Analysis

Categorical variables were compared using the $\chi^2$ test, and the Fischer exact test was used for any sample size fewer than 5. A $P$-value <0.05 was considered significant. Interrater reliability was determined using the Cohen weight and unweighted κ. The weighted κ coefficient does not necessitate exact matches, but provides greater importance to closer matches.[11] κ coefficients were classified as follows: 0.01 to 0.20 as slight agreement, 0.21 to 0.40 as fair agreement, 0.41 to 0.60 as moderate agreement, 0.61 to 0.80 as substantial agreement, and 0.81 to 1.00 as almost perfect agreement.[12–14] The association between age and Risser classification, as well as Sanders stage, was assessed using the Spearman correlation coefficient, utilizing the conventional interpretation: 0.0 to 0.19 as very weak, 0.2 to 0.39 as weak, 0.4 to 0.59 as moderate, 0.6 to 0.079 as strong, and 0.8 to 1.0 as very strong. Preceding the study, a power analysis with a 2-sided significance level of 95%, prevalence difference of 20%, and power of 80% indicated a necessary sample size of 118.

## RESULTS

### Mismatch in Skeletal Maturity

A total of 165 consecutive patients were identified, and 165 patients were enrolled with a mean of of 13.9 ± 1.7 years, and 76% of patients were female (Table 1). The risk of skeletal maturity mismatch based on the criteria of Risser stage 2 to 5 corresponding to Sanders classification of 3 to 5 was 21.8%, indicating that over 1 in 5 patients are currently undertreated. The risk of mismatch for Risser stage 0 to 1 corresponding to Sanders 6 to 7 was much less common at 3.6%.

The Spearman correlation coefficient (ρ) between age and Sanders stage was 0.61 ($n = 165$, $P < 0.0001$), demonstrating a strong positive correlation. Conversely, the correlation coefficient between age and Risser stage was 0.54, demonstrating moderate correlation ($n = 165$, $P < 0.0001$).

### Factors Associated With Skeletal Maturity Mismatch

Height, weight, BMI percentile, race, menarche, and major curve were not associated with mismatch. Males were at higher risk of mismatch compared to female patients (23.1% vs. 11.9%, $P = 0.08$). In addition, patients of Hispanic ethnicity were at a significantly higher risk of mismatch (33.3%) compared with non-Hispanic patients (8.8%, $P = 0.04$).

### Interobserver Reliability

The simple or unweighted interobserver κ for Risser staging was 0.74, and the weighted κ was 0.82. In addition, the unweighted interobserver κ for the Sanders classification was 0.86, and the weighted κ was 0.91, demonstrating almost perfect agreement. The κ value between Risser and Sanders was 0.69, demonstrating substantial agreement.

All incidences (100%) of disagreement in the Sanders classification were within 1 stage. However, disagreement in Risser classification demonstrated a difference of 1 stage in 27.3% of patients, 2 stages in 7.3%, and $\geq 3$ stages in 5.5%.

## DISCUSSION

Accurately assessing skeletal maturity is crucial data when predicting curve progression in AIS and properly counseling patients about effective treatment options such as bracing. Numerous classification systems have been devised.[15] Sauvegrain and colleagues developed a method to assess skeletal age using anteroposterior and lateral elbow radiographs to determine the level of ossification at the distal epiphysis,[15,16] and Dimeglio and Canavese subsequently introduced a simplified technique to assess age based on morphological changes in the olecranon apophysis.[15] In 1958, Risser[7] determined that complete ossification of the iliac apophysis is commonly concurrent with vertebral growth plates, and his classification system currently remains the most widely used in clinical practice. The insensitivity of Risser in detecting the rapid growth spurt has long been known,[10] and its continued use is due in no small part to the fact it can be read directly from most scoliosis films. In 2008, Sander and colleagues introduced hand radiographs as a new and reliable method. Derived from the complex Tanner-Whitehouse 3 method, which assesses morphologic changes in the metacarpals and phalanges, this system correlates more strongly with growth in idiopathic scoliosis compared with Risser staging.[9]

The correlation of stages in a classification system to bone growth and peak height velocity identifies opportunities for both nonsurgical and surgical intervention.[17–19] However, the most historic method, the Risser classification system, has noteworthy limitations that can adversely impact patient care decisions should it solely be relied upon. First, utilizing Risser to estimate bone growth prevents clinicians from distinguishing the wide range of skeletal immaturity before, during, and after rapid growth. Each of these stages presents a different risk of curve progression.[8] Maximum height velocity and two thirds of pubertal growth takes place before the first radiographic appearance of iliac apophysis ossification, rendering Risser staging insensitive to changes during this phase.[5] As the patient progresses from Risser 2 to 4, there is a minimal increase in the risk of curve progression, as it represents late adolescence and early maturity[4] (Table 2). Conversely, although Risser stage 4 is frequently believed to be a stage of curve progression cessation, it has been demonstrated that growth continues to Risser stage 5,[10,20,21] and curve progression has been documented at this stage.[22]

Second, assigning Risser stage can vary depending on country; the United States classification system divides ossification of iliac apophysis in Risser into 4 stages (Risser 1 to 4),[7] whereas the European system divides them into 3 (Risser 1 to 3).[23,24] Consequently, this may affect communication between physicians as well as research teams. Last, obtaining a posteroanterior versus anteroposterior view, which is the accurate standard for Risser, can impact interpretation. On the posteroanterior view, the iliac apophysis is externally rotated and often not fully visualized.[21] Because of the forward tilting and curvature of the iliac crest, the tangentiality of x-ray beams to the apophyseal line affect radiographic appearance.[21]

**TABLE 2.** Correlation of Sanders and Risser Stage During Phases of Bone Growth

| Sanders Stage | Radiographic Features[9] | Risser Stage | Radiographic Features |
|---|---|---|---|
| 1. Juvenile slow | Digital epiphyses are not covered | 0 | No ossification of the apophysis |
| 2. Preadolescent slow | All digital epiphyses are covered | 0 | No ossification of the apophysis |
| 3. Adolescent rapid (early) | Most digits are capped. 2nd-5th MC epiphyses are wider than metaphyses | 0 | Triradiate cartilage open (peak height velocity) |
| 4. Adolescent rapid (late) | Any of distal phalangeal physes are clearly beginning to close | 0 | Triradiate cartilage remains (open growth plates in the long bones) |
| 5. Adolescent steady (early) | All distal phalangeal physes are closed, while others are open | 0 | Triradiate cartilage closed (menarche in female patients) |
| 6. Adolescent steady (late) | Middle or proximal phalangeal physes are closing | $\geq 1$ | Ossification of the iliac apophysis ranges from 25% to 75% |
| 7. Early mature | Only distal radial physis is open. MC physeal scars may be present | 4 | 100% ossification of the iliac wing, with no fusion to iliac crest |
| 8. Mature | Distal radial physis is completely closed | 5 | Fusion of the iliac apophysis to the iliac crest (cessation of growth) |

MC indicates metacarpal.


**FIGURE 1.** Example of skeletal maturity mismatch: Risser 3 corresponding to Sanders 3.

Given these considerable limitations, the Sanders method, also known as the simplified skeletal maturity scoring system, is a widely accepted technique to determine bone age and is currently used by orthopaedic surgeons as well as other specialists, including endocrinologists.[8,25] The main benefit of this method, in comparison to the complex Tanner-Whitehouse classification 3 method from which it was derived, is its simplicity and practical use in the clinical setting. The Sanders method stratifies patients into 5 separate growth periods through the rapid adolescent growth spurt, all of which correspond to stage zero in the Risser classification system. In conjunction with both curve type and Cobb angle, Sanders is strongly prognostic of future scoliosis curve progression.[26] Adopting the Sanders classification can prevent under treatment in more than 1 of every 5 patients with AIS.

This study has shown a high rate of skeletal maturity mismatch, with a risk of 21.8% in Risser stage 2 to 5 corresponding to a Sanders 3 to 5, and an 11.5% risk with a corresponding criteria of Sanders 2 to 4 (Fig. 1). Accordingly, patients solely assessed by the Risser stage may have more growth remaining than expected, and 11.5% of patients who are assumed to be nearly mature in Risser are, in fact, in their most rapid phase of growth and therefore at high risk of progression. In addition, with a 3.6% risk of mismatch between Risser stage 0 to 1 corresponding to Sanders 6 to 7 (Fig. 2), patients evaluated by the Risser method may endure unnecessary treatment, such as bracing, which can negatively impact quality of life. Anomalous ossification of the iliac apophysis has been demonstrated, which further complicates Risser staging.[27] Finally, the association between age and Sanders demonstrated a strong correlation ($\rho = 0.61$, $n = 165$, $P < 0.0001$), compared with moderate correlation in Risser ($\rho = 0.54$, $n = 165$, $P < 0.0001$). Of note, patients of Hispanic ethnicity were at a statistically significantly higher risk of mismatch compared with non-Hispanic patients (33.3% vs. 8.8%, $P = 0.04$). This may be attributed to the finding that Hispanic children mature earlier than African American and white children.[8] In addition, diet, nutritional intake, and genetic differences impact bone growth patterns.[8] The authors do not believe that a low mean major curve has an impact on the mismatch in skeletal maturity. There is simply no literature to suggest a relationship between these 2 variables. In addition, a comparison of patients in our data set demonstrates no difference in skeletal maturity mismatch based on the major curve magnitude.

Similar to other methods of classification, Sanders does indeed have a modest learning curve, with interobserver agreement highest in those who are most experienced.[9,28] Despite this learning curve, it has been shown to be even more reliable than Risser staging. In our study, the interobserver reliability was higher in Sanders (weighted $\kappa = 0.91$) compared with Risser staging (weighted $\kappa = 0.82$), despite more experience with Risser on a historical basis. The results of interobserver reliability have been corroborated by other studies.[11]

Last, obtaining the Sanders classification does **not** require additional radiation exposure than that of a spine radiograph. Flynn implemented a Sanders bone-age quality and value initiative, which allows the hand to be captured on a spine radiograph by instructing technicians

**FIGURE 2.** Example of skeletal maturity mismatch: Risser 1 corresponding to Sanders 6.

**FIGURE 3.** Obtaining Sanders in a posteroanterior spine radiograph.

to properly position patients' hands.[29] The wrist is placed just above the shoulder, but within the view of the low-dose medical imaging system (Fig. 3).

## Strengths and Limitations

This study did not assess the longitudinal impact of utilizing Sanders classification on surgical decision marking. However, it is our institutional practice to use Sanders in informing patients about treatment options, remaining growth, and risk of progression. Second, all 3 raters, including 2 fellowship-trained spine orthopaedic surgeons and an orthopaedic nurse practitioner, have extensive experience in both Sanders and Risser staging due to our dedicated pediatric spine practice. Extensive experience may lead to higher interobserver reliability than may be typically observed in a less specialized setting.

## CONCLUSIONS

Risser staging often overestimates skeletal maturity and should not be used in determining remaining growth or guiding treatment options. This is evidenced by a 21.8% risk of mismatch in patients who appeared to be nearly skeletally mature in Risser with low risk of curve progression, but were found to actually have very significant remaining growth according to the Sanders classification. Furthermore, 11.5% who were assumed to be nearly mature according to their Risser stage, were still in their most rapid phase of growth. Given the aforementioned results and proven interobserver reliability, the authors advocate for the use of Sanders classification among surgeons managing patients with AIS.

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