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Diagnostic Performance of School-Based Scoliometric Screening for Adolescent Idiopathic Scoliosis: A Real-World Retrospective Study from a Turkish Population

onur kanlıoğlu

onur.kanlioglu532@gmail.com

tatvan devlet hastanesi

emrah karaduman

Türk Silahlı Kuvvetleri Spor Okulu

Research Article

Keywords: Scoliosis, Scoliometry, School-based Screening, Spine, Positive predictive value

Posted Date: June 17th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-9545280/v1

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Additional Declarations: No competing interests reported.

Version of Record: A version of this preprint was published at European Spine Journal on September 7th, 2026. See the published version at https://doi.org/10.1007/s00586-026-10351-2.

Abstract

Purpose: To evaluate the diagnostic performance of school-based scoliometric screening for adolescent idiopathic scoliosis (AIS) using radiographic confirmation as the reference standard in a regional population in Türkiye.

Methods: This study was designed as a Retrospective observational study using real-world data. Students referred to Tatvan State Hospital following positive school-based scoliometric screening were retrospectively analyzed. Demographic data, scoliometric findings, and radiographic measurements were extracted from hospital records. The primary outcome of the study was the positive predictive value (PPV) and the secondary outcome was the false-positive rate.

Results: A total of 170 students were included. The mean age was 12.52 ± 1.14 years. Radiographic scoliosis was identified in 15 students (8.8%). The positive predictive value of scoliometric screening was 8.8% (95% CI: 5.0–14.1), with a false-positive rate of 91.2%. Female students demonstrated a significantly higher rate of spinal imaging positivity compared to males and female sex was significantly associated with scoliosis (OR = 4.57, p = 0.049). No significant age difference was observed between groups.

Conclusion: School-based scoliometric screening demonstrated low PPV and high false-positive rates. These findings suggest that scoliometry should be considered a preliminary risk stratification tool rather than a definitive diagnostic method, and that refinement of screening thresholds may improve diagnostic efficiency and reduce unnecessary imaging.

INTRODUCTİON

Adolescent idiopathic scoliosis (AIS) is the most common spinal deformity observed during adolescence and is defined as a three-dimensional curvature of the spine with a Cobb angle of ≥10° measured in the coronal plane. Its etiology remains unclear [1]. AIS affects approximately 0.13% to 5% of school-aged children worldwide [2]. Although most curves are mild, they may demonstrate progressive behavior, particularly during periods of rapid pubertal growth. Severe cases may lead to various morbidities, including limitations in function and mobility, cardiopulmonary complications, and cosmetic concerns. Therefore, early detection of scoliosis during adolescence is crucial for appropriate monitoring, timely treatment, and prevention of complications [3].

AIS is often asymptomatic and may remain undetected in its early stages before significant curve progression occurs. Conservative treatment methods, such as bracing and exercise, have been shown to be effective in preventing curve progression when initiated in the early stages of the disease [4]. Accordingly, early identification of AIS is of great importance, as it may halt curve progression, reduce the need for surgical intervention, and improve long-term outcomes [5]. Although the clinical value and optimal implementation strategies of school-based screening programs remain controversial, such

programs are widely employed in many countries for the early detection of spinal deformities in adolescents [6].

Screening methods for AIS are generally non-invasive, cost-effective, and easy to apply. Among the available methods, the Adams forward bending test combined with scoliometric measurement of the angle of trunk rotation (ATR) is the most commonly used approach [7]. However, this method does not directly measure the magnitude of the spinal curvature but rather evaluates trunk rotation. An ATR value between 5° and 7° is generally recommended as the referral threshold for further radiological evaluation [8]. Despite its widespread use, concerns remain regarding its diagnostic accuracy, particularly in terms of specificity and high false-positive rates [5,6].

There is currently no consensus in the literature regarding the optimal balance between early detection and unnecessary referrals in scoliosis screening programs. The positive predictive value of screening varies widely across studies. Moreover, population-based studies evaluating the detection rates of scoliometer-based screening in school-aged children in Türkiye remain limited. Considering that demographic, genetic, and environmental factors may influence the distribution of AIS, data obtained from school-based populations in Türkiye may contribute to the evaluation of the applicability of scoliometer-based screening strategies.

Therefore, the present study aimed to assess the effectiveness of school-based scoliometric screening by determining the positive predictive value and false-positive rate using radiographic confirmation as the reference standard. This study seeks to contribute to the existing geographical gap in the literature by providing data from Bitlis, Türkiye, and to support the optimization of screening strategies.

METHODS

Study Design and Population

This study was designed as a retrospective, observational study conducted using real-world data from a regional school-based scoliosis screening program at Tatvan State Hospital in Bitlis, Turkey. Students who were referred for further evaluation following school-based scoliosis screening and who underwent radiographic assessment were included in the study. Students without available radiographic data were excluded from the study.

Hospital information system records were retrospectively reviewed, and a total of 170 students with available spinal radiographs following scoliometric screening constituted the study sample.

Screening Procedure

Within the school-based screening program, students were evaluated by trained healthcare personnel using the Adams forward bending test in combination with a scoliometer. The angle of trunk rotation (ATR) was measured, and students with an ATR value of ≥5° were considered suspicious for scoliosis

and referred to healthcare institutions for further radiological evaluation in accordance with commonly accepted thresholds in the literature.

Radiographic Assessment

Students who presented for further evaluation underwent standing posteroanterior spinal radiography. The presence and severity of scoliosis were determined by measuring the Cobb angle on radiographic images.

A Cobb angle of ≥10° was defined as scoliosis, whereas a Cobb angle of <10° was considered as no radiographic scoliosis.

Outcome Measures

The primary outcome of the study was the positive predictive value (PPV) of scoliometric screening for detecting radiographically confirmed scoliosis.

The secondary outcome was the false-positive rate, defined as the proportion of students with positive screening results who did not have radiographic scoliosis.

These measures were selected because the study design included only screen-positive individuals who underwent radiographic evaluation.

Statistical Analysis

Data were analyzed using the SPSS for Windows 21.0 software and a p-value of <0.05 was considered statistically significant. Descriptive statistics were used to present continuous variables as mean±standard deviation and categorical variables as frequency distributions and percentages. The normality of continuous variables was assessed using the Shapiro–Wilk test. Since variables did not follow a normal distribution, non-parametric tests were preferred for further analyses. Comparisons between two independent groups were performed using the Mann–Whitney U test for continuous variables and categorical variables were compared using the Fisher's exact test. The primary outcome measure was the PPV of scoliometric screening, defined as the proportion of students with radiographically confirmed scoliosis among those who tested positive on scoliometric screening. The false-positive rate was calculated as the proportion of students without radiographic scoliosis among those with positive screening results. In addition, 95% confidence intervals (CI) were calculated for the PPV using the Wilson method, in order to quantify the statistical uncertainty of the diagnostic performance estimate.

Ethical Approval

This study was conducted in accordance with the principles of the Declaration of Helsinki. Ethical approval was obtained from the Ethics Committee of Bitlis Eren University with approval no E-9069,

dated 07. 02. 2026, and all procedures were carried out in compliance with national and institutional research standards.

RESULTS

A total of 170 students who were referred for further evaluation following school-based scoliometric screening and underwent radiographic assessment were included in the study. 66 of the patients included in the study were male (%38.8), and 104 were female (%61.2).

The mean age of the study population was 12.52 ± 1.14 years. When analyzed by sex, the mean age was 12.48 ± 1.21 years in male students and 12.54 ± 1.11 years in female students. There were no statistically significant difference between groups. (p=0.86)

Among female students, 39 individuals (%37.5) had spinal imaging findings, whereas 14 male students (%21.2) showed spinal findings. 33 (%31.7) female student had spinal curvature including below 10 degrees and 6 (%5.7) student had kyphosis. 12 (%18.2) of male students had spinal curvature and 2 (%3) of them had kyphosis. A statistically significant difference was found between genders in terms of positive spinal imaging findings (p = 0.028).

Radiographic evaluation determined that 15 students (%8.8) had a Cobb angle greater than 10° and were diagnosed with scoliosis, while 155 students (%91.2) did not have scoliosis. Regarding scoliosis diagnosis, 13 out of 104 female students (%12.5) were diagnosed with scoliosis, while 2 out of 66 male students (%3.0) were found to have scoliosis. A statistically significant association was found between sex and radiographically confirmed scoliosis with higher prevalence observed in female students compared to males (Odds ratio=4.57, p = 0.049).

The positive predictive value (PPV) of scoliometric screening for detecting radiographically confirmed scoliosis was %8.8 (%95 CI: %5.0–%14.1). This indicates that the true PPV is expected to lie within this range, reflecting statistical uncertainty due to the limited number of confirmed scoliosis cases.

The false-positive rate was %91.2, indicating that the majority of screen-positive students did not have radiographically confirmed scoliosis. The results are presented in Table 1.

DISCUSSION

School-based screening programs for adolescent idiopathic scoliosis (AIS) have been widely implemented as part of preventive health strategies; however, their effectiveness remains controversial in the literature due to concerns regarding low diagnostic accuracy, overdiagnosis, and unnecessary imaging. While early detection of progressive spinal deformities is a primary goal, the balance between early identification and over-referral continues to challenge screening policies [9-11].

In the present study, real-world data from a regional school-based screening program in Türkiye were analyzed using radiographic confirmation as the reference standard. The findings demonstrated a low

positive predictive value (PPV) of 8.8% with a high false-positive rate of 91.2%, indicating a marked discrepancy between scoliometric screening results and radiographic confirmation of scoliosis. The upper limit of the 95% confidence interval for PPV remained below 15%, further supporting the limited specificity of scoliometry when used as a standalone screening tool.

The PPV observed in this study falls within the lower range reported in the literature. Previous large-scale school screening studies have reported PPV values ranging from approximately 5% to 40%, depending on population characteristics, examiner experience, and referral thresholds. Yawn et al. reported low diagnostic yield in a population-based school screening program in the United States, highlighting the limited effectiveness of screening in asymptomatic populations (10). Similarly, long-term follow-up studies have demonstrated that while screening may increase early detection rates, it does not significantly improve long-term clinical outcomes and is associated with substantial over-referral burden [12].

Comparable limitations have also been reported in European cohort studies, where screening performance varied depending on scoliometer cutoff values and examiner expertise [13,14]. Nissinen et al. demonstrated that trunk asymmetry is common in adolescents and does not necessarily progress to structural scoliosis, which may partly explain the low specificity of scoliometric screening [15]. In contrast, studies conducted in Asian populations have reported higher PPV values, which have been attributed to higher threshold values and population-specific differences in prevalence [11]. These variations collectively indicate that scoliosis screening performance is highly heterogeneous across different healthcare systems and populations.

The findings of the present study are consistent with these observations, as a large proportion of screen-positive individuals did not have radiographically confirmed scoliosis.

Evidence from Türkiye remains limited; however, existing studies have similarly highlighted low diagnostic accuracy and high false-positive rates in school-based scoliosis screening programs. Çolak et al. reported that school screening in Türkiye leads to a considerable number of unnecessary radiographic referrals [16]. These findings are consistent with the present study, suggesting that screening efficiency remains limited in real-world school settings in Türkiye.

Epidemiological studies conducted in different regions of Türkiye have demonstrated that scoliosis screening outcomes may vary geographically. Studies from various Anatolian regions have reported differing prevalence rates, suggesting that demographic and regional factors may influence screening performance [17-19]. Differences in healthcare infrastructure, implementation strategies, and population characteristics may further contribute to this variability. Therefore, regional data are essential for optimizing national screening policies, and the present study helps address an important geographical gap in the literature.

The high false-positive rate observed in this study may be explained by the inherent limitations of scoliometric measurement, which evaluates trunk rotation rather than structural vertebral deformity.

Postural abnormalities, physiological spinal asymmetry, pelvic tilt, and sagittal plane deformities such as kyphosis may lead to positive scoliometric findings in the absence of true scoliosis. Bunnell previously emphasized that surface-based measurements do not always correlate directly with radiographic deformity [9]. Furthermore, biomechanical studies by Labelle et al. have demonstrated that three-dimensional spinal deformity cannot be fully assessed using surface rotation measurements alone [20].

In this study, female students demonstrated higher rates of spinal imaging positivity, and female sex was significantly associated with radiographically confirmed scoliosis. This finding is consistent with previous literature indicating that AIS is more prevalent in females and has a higher risk of progression, particularly during pubertal growth spurts [3,21].

This study has several limitations. First, its retrospective design introduces inherent selection bias, as only students referred for radiographic evaluation following positive scoliometric screening were included. Therefore, individuals with negative screening results were not available for analysis, resulting in verification bias and precluding calculation of sensitivity and specificity. The relatively small number of radiographically confirmed scoliosis cases limits the precision of diagnostic performance estimates, as reflected by the wide confidence interval of the positive predictive value. The single-center design of the study and its conduction in a regional population in Türkiye may limit the generalizability of the findings to the entire Turkish population as well as to populations in other countries with different demographic characteristics and healthcare system structures, considering that screening outcomes may be influenced by population-specific and regional factors. Scoliometric measurements are inherently operator-dependent and assess trunk rotation rather than structural spinal deformity, which may lead to measurement variability and misclassification, particularly at threshold values; additionally, although radiographic imaging was performed using the same equipment, variability in image acquisition by different personnel and the absence of a fully standardized referral and imaging protocol for all screen-positive students may have introduced referral bias. Finally, the retrospective nature of the study and absence of longitudinal follow-up preclude assessment of curve progression and long-term clinical outcomes, as well as cost-effectiveness of the screening process.

CONCLUSION

This study demonstrates that school-based scoliometric screening in a Turkish regional population is associated with low positive predictive value and high false-positive rates. Although female sex was significantly associated with radiographically confirmed scoliosis, the overall diagnostic efficiency of screening remains limited. These findings suggest that scoliometry should be considered a preliminary risk stratification tool rather than a definitive diagnostic method, and that refinement of screening thresholds and protocols is necessary to improve efficiency and reduce unnecessary imaging.

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Table

Table 1 - Baseline characteristics and spinal imaging outcomes

Variables	Total (n=170)	Female (n=104)	Male (n=66)	P - Value
Age (years), mean ± SD	12.52 ± 1.14	12.54 ± 1.11	12.48 ± 1.21	0.86*
Spinal Imaging Findings (%)	53 (%31.1)	39 (%37.5)	14 (%21.2)	0.028^
Radiographic Scoliosis (Cobb >10°) (%)	15 (%8.8)	13(%12.5)	2 (%3)	0.049^
Positive predictive value (%) (95% CI)	%8.8 (%5-%14.1)			
False-positive rate (%)	%91.2			

Note: Values are presented as n (%) or mean ± SD.

*Mann Whitney-U Test

^Fisher's Exact test