Review Article

Scoliosis Screening

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ABSTRACT

The national recommendations for school screening programs for scoliosis in the United States have undergone a shift in perspective over the past two decades. In 2004, the United States Preventive Services Task Force recommended against screening programs but changed its recommendation to be inconclusive in 2018. Early diagnosis of scoliosis can allow for close monitoring of the deformity and early initiation of bracing treatment when appropriate, with the goal of preventing costly and invasive surgical intervention. Several different diagnostic tools are available, including Adam's forward bending test alone, Adam's forward bending test with scoliometry, the humpometer, and Moiré topography, each with varying degrees of sensitivity and specificity. Controversy prevails over the cost efficacy of screening programs and possible unnecessary exposure of adolescents to radiation for confirmatory radiographs after a positive screening test. However, the recent definitive evidence of bracing treatment efficacy in slowing the progression of scoliotic curves and preventing the need for surgery indicates that school screening programs may still have a role in allowing early diagnosis.

Adolescent idiopathic scoliosis (AIS) is a three-dimensional spinal deformity that results in curvature of the spine. AIS affects an estimated 0.5% to 4.2% of adolescents.[1,2] Most cases of AIS are low-magnitude deformities that are clinically insignificant with low risk of progression; however, large and progressive deformities can lead to back pain, cosmetic deformity of the trunk, and compromised pulmonary function.[3] Spinal deformity can be detected by various methods, triggering referrals to pediatric orthopaedic surgeons or spine surgeons for further management. With early detection, AIS can be monitored, and nonsurgical treatment can be implemented, when appropriate, to prevent further deformity progression. Adolescents have historically been screened in schools; however, recommendations from different task forces regarding the need for school screening for AIS and whether it is cost effective remain conflicting. For implementation of screening program, the World Health Organization lists 10 principles of an effective screening program: the disease should be an important health program, treatment should be available, facilities for diagnosing and treating should be available, a recognizable early stage should exist, a suitable test should exist, this test should be acceptable to the cohort, the natural history of the disease should

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be understood, a policy on who needs treatment should exist, the process should be cost-effective, and screening should be continuous.[4] Although most of these principles are currently met, the debate regarding the suitable test and cost efficacy is ongoing.

History of School Screening and Current Implementation in the United States

Screening for AIS began in the 1960s; with the eradication of tuberculosis and polio, a new focus on detecting spinal curvature that appeared to be idiopathic emerged.[3] Screening began in Aitken, Minnesota, in 1963, and in 1978, Delaware was the first state to adopt mandatory screening.[5] By 2003, 21 states had mandated school screening, whereas 11 others recommended it. Partly because of the 2004 United States Preventive Services Task Force (USPTSF) recommendation against routine school screening, the number of states with school screening slowly declined, and as of 2019, only 15 states continue to mandate school screening.[6,7]

A major flaw in the implementation of mandatory scoliosis school screenings is that the frequency and timing of screening are not standardized between states. Some states recommend only a single screening around grade 6 or 7, whereas others recommend yearly screenings from grades 5 to 9. Screenings are often performed by school nurses or licensed health professionals, but they may also be performed by non–health practitioners attending a screening certification class.[6] The methods of screening are not specified, and each state has different protocols. For example, in Texas, students are evaluated in their sixth and ninth grades for physical examination findings of asymmetry and by an Adams forward bending test (FBT), with optional use of a scoliometer. If a child is found to have any positive findings on a screening test, they are retested 2 to 3 weeks later. If on repeat examination, the child continues to have positive findings of scoliosis, a letter is sent to their parent or parents requesting evaluation by a physician.[8] The heterogeneity of these screening programs, the subsequent variations in program effectiveness, and varying percentages of false-positive screenings all call into question the utility and societal benefit of these nonstandardized school screening programs.

Available Screening Tests

Forward Bending Test

The forward bending test (Figure 1) is the simplest test to screen for scoliosis. This screening method does not require any instruments or devices to perform.[8,9] The patient stands facing away from the examiner and bends forward at the waist until the spine is horizontal to the ground. The examiner assesses the child for asymmetry of the back, ribs, and shoulders. Any asymmetry of the contour of the posterior rib cascade indicates a rotation of the thorax and is considered a positive test.

Scoliometer

The scoliometer (Figure 2) is an instrument that can be used in combination with the FBT that quantifies the degree of spinal rotation. The instrument is placed on the patient's back at the point of maximal asymmetry with the patient bent forward at the waist. A reading greater than 5 to 7° generally indicates a rotational deformity significant enough to warrant referral to a specialist.[8,9] The utility of the scoliometer differs based on the degree of rotation used for a positive result. Using a cutoff of 5° allows for maximal disease detection (low false-negative rate) but will increase false-positive referrals, thus increasing the number of unnecessary referrals. However, a cutoff of 7° will decrease false-positive results subsequently decreasing unnecessary referrals but may miss some patients with treatable deformities (increased false-negative results). The scoliometer is now available as a clinically valid electronic application on modern smart phones.[10]

Moiré Topography

In Moiré topography (Figure 3), a lighted imaging device projects a series of curved lines onto the patient's back. The contours of the back distort the projected lines, creating a three-dimensional topographic map on the patient's back, which is then photographed. The picture can then be evaluated for asymmetry in the markings, known as Moiré fringes. If two or more asymmetric Moiré fringes are present, the patient is referred to a specialist.[11]

Humpometer

The humpometer (Figure 4) is a less commonly used screening tool. It is used to perform a noninvasive test in which bendable strips are placed perpendicular to the spine at different levels. The strips bend to the topography of the back and are locked into place. The strips are then traced onto paper, and the curve is evaluated by measuring the difference in deformity between the right and left sides of the back at multiple spinal levels. A deformity of 5 mm, which is the sum of the right and left sides' deviation from neutral, warrants a referral to a specialist.[9,12]

Figure 1

Photographs showing the Adam's forward bending test: patient standing upright and then bending forward at waist, followed by a radiograph of the spine demonstrating scoliosis.

Efficacy of Scoliosis Screening Tests

Several studies have assessed the accuracy of each screening test, in isolation and in combination. Karachalios and colleagues followed 2,700 students in Greece over 10 years and assessed each with the FBT, Moiré topography, the humpometer, and a scoliometer. The FBT had a sensitivity of 84.4% and specificity of 93.4%, and the scoliometer had a sensitivity of 90.6% and specificity of 79.8%. Moiré topography had a sensitivity of 100% and specificity of 85.4%, and the humpometer had a sensitivity of 93.8% and specificity of 78.1%. The conclusion was that the FBT alone was not adequate for screening students (Table 1).[12]

Alone, a scoliometer has been shown to have a sensitivity of 87% and specificity of 34% when using a 5° cutoff in detecting scoliosis Cobb angles ≥10°. Using a 7° cutoff, the sensitivity is 62%, and specificity is 75%.[13]

A few studies have looked at one-time screening of students with an FBT and a scoliometer and have found a positive predictive value ranging from 34.3% to 41.2%.[14–16] Yawn and colleagues conducted a longitudinal study of 2,242 students in Minnesota who underwent screening with FBT and a scoliometer. Using this combination to detect a Cobb angle of ≥10°, they had a positive predictive value of 29.3%, sensitivity of 71.1%, and specificity of 97.1%. The false-positive rate was 2.9%, and the false-negative rate was 28.9%.[17]

Early studies of Moiré topography were discouraging, given low accuracy and increased cost compared with an FBT and scoliometer test.[18] In 1983, Moreland found Moiré topography to have an accuracy of 93 to 100% in identifying the presence of a curve.[18] In 1985, Daruwalla studied 1,342 students in Singapore with Moiré topography and found an overall accuracy of 95.7% in its ability to detect the presence of a curve. However, the location of the curve affected the accuracy of the test, with the accuracy ranging from 15% in the lumbar region to 85% in the thoracic region. Daruwalla's study had a high false-positive rate of 12.5%, which was attributed to patient positioning. Given the high false-positive rate and the extra expense required to purchase and run the equipment needed for Moiré topography, Daruwalla concluded that the FBT was more efficient and suitable for screening programs.[18] Yamamoto and colleagues performed a retrospective study on 195,159 students in Japan who underwent Moiré topography for scoliosis screening and found a false-positive of 66.7%. The conclusions by Yamamoto were similar to those of Daruwalla regarding the use of Moiré topography in isolation.[19]

The most comprehensive evaluation of this student screening was completed on the Hong Kong student cohort by Fong and Luk. 306,082 students in Hong Kong were screened by an FBT and a scoliometer, and if positive, the students were then and there referred for Moiré

Figure 2

Image of a scoliometer being used to assess a patient's deformity. Reproduced/adapted with permission from Zaborowska-Sapeta K, Gizewski T, Binkiewicz-Glinska A, Kamelska-Sadowska AM, Kowalski IM: The duration of the correction loss after removing cheneau brace in patients with adolescent idiopathic scoliosis. Acta Traumatol Turc 2019;53(1):61-67.

Figure 3

Image of Moiré topography. The patient stands with his chest to the wall, and the Moiré lines are projected onto his backs; the test administrator takes a photograph of the resulting projection. Reproduced/adapted with permission from Porto F, Gurgel JL, Russomano T, Farinatti PDTV: Moiré topography: characteristics and clinical applications. *Gait & Posture* 2010;32(3):422-424.

testing. Using this two-step technique to detect curves of ≥10°s, the sensitivity of testing was 93.8%, specificity 99.2%, false positive 0.8%, false negative 6.2%, and positive predictive value was 81%. With the use of this two-tiered approach to screening, it was concluded that this approach, referrals were more appropriate and false positives were acceptably low, leading to radiation of few inappropriate patients.[20,21]

Finally, using the Hong Kong data, Lee and colleagues looked at the value of angle of trunk rotation (ATR) measured by the scoliometer to determine the best cutoff for referral rates and accuracy of diagnosis. Alone, a scoliometer measurement with a cutoff of 5° had a referral rate of 8.6%, which decreased to 1.6% at a 10° cutoff. When Moiré topography was added to the evaluation, a minimum scoliometer cutoff value of 9° with a positive Moiré led to a referral of 3.1%. When all three tests were used (ie, FBT, scoliometer, and Moiré), the accuracy of detecting scoliosis did not differ with the use of scoliometer cutoff values between 9 and 15°. However, referral rates to specialists were lowest when the scoliometer measurement of 15 was used as a cutoff. Thus, they recommended using a scoliometer value of 15° as the cutoff for referral when used in conjunction with the FBT and Moiré test.[22]

These studies have shown that any one test in isolation lacks specificity and sensitivity for detecting scoliosis. Moiré topography is user dependent and expensive given the required equipment. An FBT when used in conjunction with a scoliometer with a 7° cutoff can be an inexpensive and easily performed screening option.

Task Force Recommendations, Past and Present

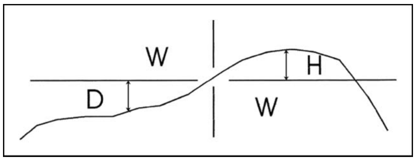
USPSTF

The United States Preventive Services Task Force (USPSTF) is a panel of experts that analyzes the available peer-reviewed evidence regarding a specific preventive service or intervention. After analysis, the task force assigns a letter grade (A-D) indicating their recommendation for or against the intervention based on the certainty of the evidence and the balance of benefits and harms of the service assessed. A letter grade of I is given for services that have insufficient evidence to assess the balance of benefits and harms or services that have conflicting or poor quality data.[7]

In 1994, the initial USPSTF recommendation for routine screening of adolescents for scoliosis by schools or community programs was an "I" because of insufficient evidence. In 2004, the USPSTF changed their recommendation to being against the screening program, assigning it a letter D (No net benefit of this service; task force discourages use of this service). The task force cited lack of evidence that screening detected deformity earlier than would otherwise be detected and that the FBT had variable accuracy. The recommendation noted that screening benefited only a small portion of the cohort and treatment led to harm, including unnecessary referrals, radiography, and brace wear.[7]

In 2018, the USPSTF changed their recommendation back to an "I." The task force noted that the accuracy of screening is high when using three different screening tests. They noted that no studies had proved that

Figure 4



A humpometer line drawing. After the magnetic strips are locked onto the patient's back, the strip can be traced, resulting in a line like this example. H = hump, D = depression; H + D = deformity. Reproduced/adapted with permission from Karachalios T, Sofianos J, Roidis N, Sapkas G, Korres D, Nikolopoulos K: Ten-year follow-up evaluation of a school screening program for scoliosis. Is the forward-bending test an accurate diagnostic criterion for the screening of scoliosis? Spine (Phila Pa 1976) 1999;24(22):2318-2324.

patients were harmed by the screening of scoliosis or its early detection and that early detection allowed treatment with bracing treatment, which has been shown to be effective at preventing deformity progression. This recommendation leaves the use of screening for scoliosis to the clinical judgment of individual physicians until more data on the subject are generated.[9,23,24]

American Academy of Orthopaedic Surgeons/Scoliosis Research Society/Pediatric Orthopaedic Society of North America/American Academy of Pediatrics

In response to the 2004 USPSTF recommendation against scoliosis screening, the American Academy of Orthopaedic Surgeons, the Scoliosis Research Society (SRS), the Pediatric Orthopaedic Society of North America (POSNA), and the American Academy of Pediatrics endorsed a statement by Richards and Vitale regarding scoliosis screening in 2008.[1] The professional groups jointly "[did] not support any recommendation against scoliosis screening, given available evidence."[1] They noted that earlier detection and treatment, both surgical and nonsurgical, had potentially substantial benefits to the patients. They recommended that if screening were to occur, females be screened at both ages 10 and 12 years and boys be screened once at either age 13 or 14 years, using an FBT and scoliometer for screening.

In 2013, an International Task Force of the SRS released a consensus statement that evaluated screening for AIS based on five domains that were modified from the World Health Organization's 10 domains for validity of a screening program. The recommendations for screening method and frequency were the same as were described by Richards and Vitale.[1] Four of the five domains (ie, technical efficacy, clinical effectiveness, program effectiveness, and treatment effectiveness) were supportive of screening, whereas evidence regarding cost-effectiveness was not sufficient.[25]

In 2015, a new position statement was issued by the SRS, Pediatric Orthopaedic Society of North America, AAOS, and American Academy of Pediatrics asking the USPSTF to reconsider their 2004 position against screening.[23] They cited the recently published data on bracing treatment that showed that early bracing treatment could decrease the need for surgical interventions.[24] This position statement was the impetus for the USPSTF to rereview the current data and change the recommendation for screening to an "I."

International Recommendations

Society on Scoliosis Orthopaedic and Rehabilitation Treatment Consensus

The International Society on Scoliosis Orthopaedic and Rehabilitation Treatment (SOSORT) published a consensus article in 2007 on the use of school screening programs. The cohort recommended school screening, citing the efficacy of early intervention with bracing treatment and patient exercise programs that can alter the progression of disease. To decrease the unnecessary referrals, they recommended having objective criteria for referrals for patients who are treatment eligible, rescreening borderline patients at a later date before referral, and screening only females. In addition, because of the increase in AIS found in the northern latitudes and the later onset of menarche in more northern countries, this group suggested that the age of screening be adjusted by location. The consortium recommended screening using an FBT in the sitting position so as to eliminate the effects of leg length discrepancy and pelvic obliquity. Finally, they recommended that a well-organized and voluntary program be developed to help minimize cost.[5]

United Kingdom

The United Kingdom National Screening Committee (UK NSC) released a statement in 2012 and another again in 2016 against a national AIS screening program. Their recommendation was based on concerns of a lack of specific criteria prompting further testing and the likelihood of radiation exposure with further testing.[26,27]

Japan

In Japan, scoliosis school screening was mandated by law in 1978, but its implementation and compliance varies by region. Some regions use the FBT in conjunction with the scoliometer, whereas others use Moiré topography.[11]

Table 1. Results From Prospective Cohort Studies on Accuracy of Scoliosis Screening

Source (Country)	No. Screened	Screening Test (Screening Frequency)	% (95% CI)			%		
			PPV	Sensitivity	Specificity	False-Positive Rate	False-Negative Rate	Prevalence of AIS with >10° Cobb Angle
Screening programs with follow-up of screen-negative children								
Yawn et al, 1999[17] (United States)	2,242	FBT +/− scoliometer (annual over multiple years)[a]	29.3 (20.3-39.8)	71.1 (54.1-84.6)	97.1 (96.3-97.7)	2.9	28.9	1.7
Fong et al, 2015[20]	—	—	—	—	—	—	—	—
Lee et al, 2010[22]	—	—	—	—	—	—	—	—
Luk et al, 2010[21] (Hong Kong)	306,082	FBT +/− scoliometer +/− Moiré topography (biennial or more often)	81.0 (80.3-81.7)	93.8 (93.3-94.3)	99.2 (99.2-99.2)	0.8	6.2	3.5
Karachalios et al, 1999[12] (Greece)	2,700	FBT (one time)	17.3 (11.7-24.2)	84.4 (67.2-94.7)	95.2 (94.3-95.9)	4.8	15.6	1.2
	2,700	Scoliometer (one time)	5.3 (3.6-7.6)	90.6 (75.0-98.0)	80.7 (79.1-82.1)	19.3	9.4	1.2
	2,700	Moiré topography (one time)	7.6 (5.3-10.6)	100.0 (84.2 (100)	85.4 (84.0-86.7)	14.6	0	1.2
	2,700	Humpometer (one time)	5.0 (3.4-7.0)	93.8 (79.2-99.2)	78.5 (76.9-80.0)	21.5	6.3	1.2
Screening programs with no follow-up of screen-negative children								
Goldberg et al, 1993, 1995[16,41,42] (Ireland)	8,669	FBT + scoliometer (one time)	54.1 (40.8-66.9)	NR	NR	NR	NR	0.4
Wong et al, 2005[15] (Singapore)	40,649	FBT + scoliometer (one time)	41.2 (37.4-45.1)	NR	NR	NR	NR	0.7
Adobor et al, 2011[14] (Norway)	4,000	FBT + scoliometer (one time)	36.7 (24.6-50.1)	NR	NR	NR	NR	0.6

AIS = adolescent idiopathic scoliosis; CI = confidence Interval; FBT = forward bending test; NR = not reported; PPV = positive predictive value

Recreated from: Dunn J, Henrikson NB, Morrison CC, Blasi PR, Nguyen M, Lin JS: Screening for adolescent idiopathic scoliosis: evidence report and systematic review for the US Preventive Services Task Force. *JAMA* 2018;319(2):1730-187.

Australia

Scoliosis screening in schools was abandoned by Australia, but the government introduced the National Self-Detection Program for Scoliosis in its stead. Each year, schools are asked to distribute a Self-Detection Fact Sheet to girls between 10 and 12 years of age. The sheet recommends that families perform the FBT and, if signs of scoliosis are noted, discussing it with the primary care doctor.[28–30]

Canada

Canada mandated scoliosis screening in the 1970s, but it was discontinued in the 1980s. Currently, the Canadian Task Force on Preventive Health Care does not list scoliosis within their published guidelines for preventive measures.[5,30]

Norway

Norway previously mandated school screening programs, but screening was abolished in 1994 in the wake of the USPSTF original recommendation against this screening.[31]

Hong Kong

In Hong Kong, screening for scoliosis is voluntary but has been provided by the Department of Health since 1995 for students in grades 5, 7, and 9. Students are first assessed at a Student Health Service Centre using the FBT and a scoliometer. If found positive (scoliometer 5 to 14°), they are referred to a Special Assessment Center for assessment using Moiré topography and a scoliometer. If Moiré topography reveals two or more asymmetric lines, they are referred to a specialist. If initial testing reveals a scoliometer reading of >14, they are referred directly to a specialist.[21,32]

School Screening: Cost and Efficacy

Randomized control trials on the effectiveness of screening for AIS are lacking. Because each country has a different policy for school screening and methodology for conducting the screening, the studies describing the screening cost and efficacy are not homogenous.

Yawn and colleagues evaluated 2,242 students screened in Rochester, Minnesota, using an FBT and scoliometer. The threshold for referral was two positive consecutive screenings with a scoliometer measure greater than 6°. They found that the 4.1% of their cohort required referrals for evaluation, but the positive predictive value (PPV) for patients requiring treatment for curves was 5%. Per the data, an estimated 450 students had to be screened to find one that required treatment.[17] A follow-up study by Yawn in 2000 found that the screening in Rochester, MN, cost $34.40 per child screened. It cost $4,198.67 to find one child who had a curve of ≥20°, and $15,115.20 to find one child who needed treatment for scoliosis (either bracing treatment or surgery).[33] For cost-comparison, a study by Martin and colleagues found that the cost for one AIS surgery in 2011 averaged over $155,278.[34]

Several studies have been done using the Hong Kong scoliosis screening cohort because the screening is free to students, although not mandatory. Fong et al performed a study of 394,401 students in the fifth grade with 10-year follow-up. Of the 306,114 students who electively were screened, a total of 7.3% were referred to specialists for either radiographic findings or clinical findings concerning for AIS. Overall AIS prevalence was 3.5% for those screened; 0.2% had curves ≥40° and 0.4% required treatment. Of the 88,257 students who did not participate in the screening, 0.6% were diagnosed with AIS by age 19 years. Using their two-tiered referral process to a specialist, the PPV was 81% for curves ≥10°, 39.8% for curves ≥20°, 4.6% for curves ≥40°, and 8.4% for treatment.[20]

Lee et al looked at the cost of school screening in Hong Kong in 2010 and found that the average cost per student was $34.61 USD, per student with a curve ≥20 was $4,4475.67 USD, and cost per student requiring treatment was $20,768.29 USD. At the level of cost per student screened, they found results similar to those of the Minnesota cohort.[32]

A study from Singapore by Thilagaratnam et al did a cost analysis of school screening. The study calculated the presumed cost of treatment as if all patients who underwent bracing treatment required surgery instead, simulating a missed opportunity for early diagnosis through screening. They compared this simulated cost with the actual cost of screening and subsequent treatment for the cohort. The cost of care for the nonscreened cohort was approximately 28% more than that of the screened cohort. The study concluded that screening was cost-effective for the Singaporean cohort.[35]

Several studies have concluded that the use of FBT alone increases the rate of referrals and has a high false-negative and positive rate for detecting AIS, leading to missed diagnoses and inappropriate referrals.[12,36,37] A study in Nara City, Japan, also noted that Moiré topography, when used in isolation, had a high false-positive rate, leading to excessive referrals and radiation.[19] The general consensus is that screening programs that use FBT or Moiré in association with other tests leads to improvement in the PPVs of screening programs.[19,36]

Ohrt-Hissen et al and Adobor et al conducted studies in Denmark and Norway, respectively, on populations without school screening programs to assess the referral patterns and patient characteristics at the time of referral.[31,38] In Copenhagen, they found that the average age of referral was 15 years, and the Cobb angle was 35°; 33% of patients required bracing treatment. They found the presence of a larger curve at the time of referral compared with the cohort in the literature, with 22% having a Cobb angle of greater than 40°, compared with 8% in the Hong Kong screened cohort.[38] Adobor et al found a similar average Cobb angle to Ohrt-Hiessen's cohort at the time of referral. They noted that 71% of referred curves were detected by family or friends and that 61% of the patients were referred by orthopaedic surgeons, as opposed to school nurses or primary care doctors.[31] Without a screening program, a significant contributor to late referrals is the lack of continuity of care by primary care providers.[37]

Future Considerations Regarding School Screening in the United States

Impact of Bracing Treatment Efficacy

The Bracing in Adolescent Idiopathic Scoliosis Trial (BRAIST) in 2013 demonstrated success with bracing AIS curves of 20 to 40°, with the trial being terminated early because of the superiority of bracing treatment over observation. The trial found that only three patients were required to be treated to prevent one case progressing to surgery.[24] A subsequent study by Sanders et al found that in patients with 25 to 45° curves, the number needed to treat (NNT) with bracing varied by compliance with brace wear. The NNT across all patients prescribed bracing treatment in the study was 7, whereas for those with high compliance of brace wear (≥10 hours per day), the NNT was 3.[39] Bracing treatment efficacy is improved with increased use of the brace, as well as earlier Risser stage and open triradiate cartilage.[24,39] These studies highlight the importance of early detection of AIS curves because subsequent treatment with bracing treatment can potentially avoid eventual surgery.

Radiation Exposure

A concern for early screening is that patients are subjected to radiation after a positive screening.[26] However, new low-dose slot-scanning radiograph systems that produce high-quality imaging are available in some pediatric orthopaedic centers. These systems have been shown to use less radiation with equivalent image quality compared with conventional radiograph systems. A 2015 study by Luo et al calculated the estimated radiation exposure of a group of patients with AIS who either underwent bracing treatment or surgery and were followed to skeletal maturity. The average number of radiographs obtained was 20.8, with those who underwent surgery requiring more radiographs than those who were braced. Compared with conventional radiography, the microdose slot-scanning radiography system decreases radiation by 50%, which is cumulatively nearly 1 year of background radiation.[40] Given the minimization of radiation using newer technology and more judicious use of radiography, the issue of radiation exposure seems to be less of a concern with screening of patients.

Summary

The current national recommendations for scoliosis screening in the United States remain inconclusive, leading to inconsistent school screening programs between the states. Certainly, regular screening for scoliosis has the following benefits: (1) several reliable examination and screening techniques are available for detecting scoliosis in adolescents; (2) earlier detection of scoliosis allows for initiation of bracing treatment, which may be more effective (ie, earlier patient age and smaller curve magnitude); and (3) bracing treatment of scoliosis can prevent major surgery. Despite these advantages, unresolved issues still prevent this screening from gaining wide-spread acceptance: (1) screening programs have been shown to be costly, (2) a widely accepted standard method or the age for scoliosis screening lacks a consensus, and (3) many recommendations for screening have inherent bias from groups invested in scoliosis care. Although the goal of any disease screening process is early detection leading to early intervention and long-term health improvement, the data supporting scoliosis screening are at best weak and inconclusive. Given the rising cost of surgical intervention for adolescent idiopathic scoliosis and the proven benefit of bracing treatment for scoliosis to decrease the need for surgical intervention, work should be targeted at determining the cost benefit of screening programs on a state-by-state basis, as well as the cost of bracing treatment and surgery. The next step would be to standardize the process and timing of scoliosis screening in an effort to improve the utility of this service.

References

References printed in **bold type** are those published within the past 5 years.

1. Richards BS, Vitale MG: Screening for idiopathic scoliosis in adolescents. An information statement. *J Bone Joint Surg Am* 2008;91: 195-198.

2. Konieczny MR, Senyurt H, Kraupse R: Epidemiology of adolescent idiopathic scoliosis. *J Child Orthop* 2013;7:3-9.

3. Linker B: A dangerous curve: The role of history in America's scoliosis screening programs. *Am J Public Health* 2012;102:606-616.

4. Wilson JMG, Jungner G: *Principles and Practice of Screening for Disease*. Geneva, Switzerland: World Health Organization; 1968.

5. Grivas TB, Hresko MT, Labelle H, Price N, Kotwicki T, Maruyama T: The pendulum swings back to scoliosis screening: Screening policies for early detection and treatment of idiopathic scoliosis- current concepts and recommendations. *Scoliosis* 2013;8:16.

6. Jakubowski TL, Alexy EM: Does school scoliosis screening make the grade? *NASN Sch Nurse* 2014;29:258-265.

7. U.S. Preventative Services Task Force: *Screening for idiopathic scoliosis in adolescents: Recommendation statement*, 2004. Available at: https://www.uspreventiveservicestaskforce.org/Page/Document/UpdateSummaryFinal/idiopathic-scoliosis-in-adolescents-screening. Accessed November 29, 2018.

8. Texas Department of State Health Services: Spinal screening program, school spinal screening guidelines. Available at: https://dshs.texas.gov/spinal/pdf/SpinalScreenGuidelines092018.pdf. Accessed October 20, 2019.

9. US Preventative Services Task Force: Screening for adolescent idiopathic scoliosis: US preventative services task force recommendation statement. *JAMA* 2018;319:165-172.

10. Franko OI, Bray C, Newton PO: Validation of a scoliometer smart phone app to assess scoliosis. *J Pediatr Orthop* 2012;32:e72-e75.

11. Kuroki H, Nagai T, Chosa E, Tajima N: School scoliosis screening by Moiré topography- overview for 33 years in Miyazaki Japan. *J Orthop Sci* 2018;23:609-613.

12. Karachalios T, Sofianos J, Roidis N, Sapkas G, Korres D, Nikolopoulos K: Ten-year follow-up evaluation of a school screening program for scoliosis. Is the forward-bending test an accurate diagnostic criterion for the screening of scoliosis? *Spine* 1999;24:2318-2324.

13. Negrini S, Donzelli S, Aulisa AG, et al: 2016 SOSORT guidelines: Orthopaedic and rehabilitation treatment of idiopathic scoliosis during growth. *Scoliosis Spinal Disord* 2018;13:3.

14. Adobor RD, Rimeslatten S, Steen H, Brox JI: School screening and point prevalence of adolescent idiopathic scoliosis in 4000 Norwegian children aged 12 years. *Scoliosis* 2011;6:23.

15. Wong HK, Hui JHP, Rajan U, Chia HP: Idiopathic scoliosis in Singapore schoolchildren: A prevalence study 15 years into the screening program. *Spine* 2005;30:1188-1196.

16. Goldberg CJ, Dowling FE, Hall JE, Emans JB: A statistical comparison between natural history of idiopathic scoliosis and brace treatment in skeletally immature adolescent girls. *Spine* 1993;18:902-908.

17. Yawn BP, Yawn RA, Hodge D, et al: A population-based study of school scoliosis screening. *JAMA* 1999;282:1427-1432.

18. Daruwalla JS, Balasubramaniam P: Moiré topography in scoliosis: Its accuracy in detecting the site and size of the curve. *J Bone Joint Surg Br* 1985;67:211-213.

19. Yamamoto S, Shigematsu H, Kadono F, et al: Adolescent scoliosis screening in Nara city schools: A 23-year retrospective cross- sectional study. *Asian Spine J* 2015;9:407-415.

20. Fong DY, Cheung KM, Wong YW, et al: A population-based cohort study of 394,401 children followed for 10 years exhibits sustained effectiveness of scoliosis screening. *Spine J* 2015;15:825-833.

21. Luk KD, Lee CF, Cheung KM, et al: Clinical effectiveness of school screening for adolescent idiopathic scoliosis: A large population-based retrospective cohort study. *Spine* 2010;35:1607-1714.

22. Lee CF, Fong DY, Cheung KM, et al: Referral criteria for school scoliosis screening: Assessment and recommendations based on a large longitudinally followed cohort. *Spine* 2010;35:1061-1071.

23. Dunn J, Henrikson NB, Morrison CC, Blasi PR, Nguyen M, Lin JS: Screening for adolescent idiopathic scoliosis: Evidence report and systematic review for the US preventative services task force. *JAMA* 2018;319:173-187.

24. Weinstein SL, Dolan LA, Wright JG, Dobbs MB: Effects of bracing in adolescents with idiopathic scoliosis. *N Engl J Med* 2013;369:1512-1521.

25. Labelle H, Richards SB, De Kleuver M, et al.: Screening for adolescent idiopathic scoliosis: An information statement by the scoliosis research society international task force. *Scoliosis* 2013;8:17.

26. UK National Screening Committee: UK NSC recommendation on adolescent idiopathic scoliosis (AIS), 2016. Available at: https://legacyscreening.phe.org.uk/screening-recommendations.php. Accessed November 29, 2018.

27. UK National Screening Committee: Screening for adolescent idiopathic scoliosis: External review against programme appraisal criteria for the UK National Screening Committee (UK NSC). Available at: https://legacyscreening.phe.org.uk/policydb_download.php?doc=633. Accessed October 14, 2019.

28. Scoliosis Australia: *Adolescent Scoliosis Spinal Curvature Fact Sheet*, 2020. Available at: https://www.scoliosis-australia.org/wp-content/uploads/Self-Detection_FactSheet.pdf. Accessed January 10, 2020.

29. Scoliosis Australia: The national self-detection program for scoliosis. Available at: https://www.scoliosis-australia.org/wp-content/uploads/national_self_detection_program_for_scoliosis.pdf. Accessed October 15, 2019.

30. Plaszewski M, Nowobilski R, Kowalski P, Cieslinski M: Screening for scoliosis: Different countries' perspectives and evidence-based health care. *Int J Rehabil Res* 2012;35:13-19.

31. Adobor RD, Riise RB, Sorensen R, Kibsgard TJ, Steen H, Brox JI: Scoliosis detection, patient characteristics, referral patterns and treatment in the absence of a screening program in Norway. *Scoliosis* 2012;7:18.

32. Lee CF, Fong DY, Cheung KM, et al: Costs of school scoliosis screening: A large, population-based study. *Spine* 2010;35:2266-2272.

33. Yawn BP, Yawn RA: The estimated cost of school scoliosis screening. *Spine* 2000;25:2387-2391.

34. Martin CT, Pugely AJ, Gao Y, et al: Increasing hospital charges for adolescent idiopathic scoliosis in the United States. *Spine* 2014;39:1676-1682.

35. Thilagaratnam S: School-based screening for scoliosis: Is it cost-effective?. *Singapore Med J* 2007;48:1012-1017.

36. Fong DY, Lee CF, Cheung KM, et al: A meta-analysis of the clinical effectiveness of school scoliosis screening. *Spine* 2010;35:1061-1071.

37. Beausejour M, Goulet L, Ehrmann Feldman D, et al: Pathways of healthcare utilisation in patients with suspected adolescent idiopathic scoliosis: A cross sectional study. *BMC Health Serv Res* 2015;15:500.

38. Ohrt-Nissen S, Hallager DW, Henriksen JL, Gehrchen M, Dahl B: Curve magnitude in patients referred for evaluation of adolescent idiopathic scoliosis: Five years' experience from a system without school screening. *Spine Deform* 2016;4:120-124.

39. Sanders JO, Newton PO, Browne RH, Katz DE, Birch JG, Herring JA: Bracing for idiopathic scoliosis: How many patients require treatment to prevent one surgery?. *J Bone Joint Surg Am* 2014;96:649-653.

40. Luo TD, Stans AA, Schueler BA, Larson AN: Cumulative radiation exposure with EOS imaging compared with standard spine radiographs. *Spine Deform* 2015;3:144-150.

41. Goldberg CJ, Dowling FE, Fogarty EE: Adolescent idiopathic scoliosis: Is rising growth ate the triggering factor in progression? *Eur Spine J* 1993;2: 29-36.

42. Goldberg CJ, Dowling FE, Fogarty EE, Moore DP: School scoliosis screening and the United States preventative services task force: An examination of the long-term results. *Spine* 1995;20:1368-1374.