JAMA | US Preventive Services Task Force | EVIDENCE REPORT

# Screening for Adolescent Idiopathic Scoliosis
## Evidence Report and Systematic Review for the US Preventive Services Task Force

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**IMPORTANCE** Adolescent idiopathic scoliosis (AIS), a spinal curvature of 10° or more, is the most common form of scoliosis, with a prevalence of 1% to 3%. Curves progress in approximately two-thirds of patients with AIS before skeletal maturity, and large curves (>50°) may be associated with adverse health outcomes.

**OBJECTIVE** To systematically review evidence on benefits and harms of AIS screening for the US Preventive Services Task Force (USPSTF).

**DATA SOURCES** Cochrane Central Register of Controlled Trials, MEDLINE, ERIC, PubMed, CINAHL, and relevant systematic reviews were searched for studies published from January 1966 to October 20, 2016; studies included in a previous USPSTF report were also reviewed. Surveillance was conducted through July 24, 2017.

**STUDY SELECTION** Fair- and good-quality studies that evaluated the accuracy of screening children and adolescents aged 10 to 18 years for AIS, the benefits of AIS treatment, the harms of AIS screening or treatment, or long-term health outcomes.

**DATA EXTRACTION AND SYNTHESIS** Two investigators independently reviewed abstracts and full-text articles and extracted data into evidence tables. Results were qualitatively summarized.

**MAIN OUTCOMES AND MEASURES** Health outcomes and spinal curvature in adolescence and adulthood, accuracy of screening for AIS, any harm of AIS screening or treatment.

**RESULTS** Fourteen studies (N = 448 276) in 26 articles were included. Accuracy of AIS screening was highest (93.8% sensitivity; 99.2% specificity) in a cohort study of a clinic-based program using forward bend test, scoliometer, and Moiré topography screening (n = 306 082); accuracy was lower in cohort studies of 6 programs using fewer modalities (n = 141 161). Four controlled studies (n = 587) found evidence for benefit of bracing on curve progression compared with controls. A randomized clinical trial and a nonrandomized trial of exercise treatment (N = 184) found favorable reductions in Cobb angle of 0.67° to 4.9° in the intervention group compared with increases of 1.38° to 2.8° in the control group. Two cohort studies (n = 339) on long-term outcomes found that braced participants reported more negative treatment experience and body appearance compared with surgically treated or untreated participants. A study that combined a randomized clinical trial and cohort design (n = 242) reported harms of bracing, which included skin problems on the trunk and nonback body pains. There was no evidence on the effect of AIS screening on adult health outcomes.

**CONCLUSIONS AND RELEVANCE** Screening can detect AIS. Bracing and possibly exercise treatment can interrupt or slow progression of curvature in adolescence. However, there is little or no evidence on long-term outcomes for AIS treated in adolescence, the association between curvature at skeletal maturity and adult health outcomes, the harms of AIS screening or treatment, or the effect of AIS screening on adult health outcomes.

*JAMA*. 2018;319(2):173-187. doi:10.1001/jama.2017.11669

Editorial page 127

Related article page 165 and JAMA Patient Page page 202

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Adolescent idiopathic scoliosis (AIS) is traditionally defined as a lateral curvature of the spine of 10° or more in persons aged 10 to 18 years that is not a result of an underlying condition (a glossary of terms appears in the **Box**). It is the most common form of scoliosis[9-11] and occurs more commonly in females.[12,13] Estimates from screening studies dating from 1985 to 2011 suggest that the prevalence of AIS ranges from 0.5% to 5.2%.[6,12] Because two-thirds of patients with AIS experience curve progression during adolescence[14] and progression into adulthood is more likely in those with curves greater than 40° at the end of growth,[15-18] treatment is focused on slowing curve progression before skeletal maturity. Patients with AIS who have mild curves do not appear to have clinically important symptoms during adolescence, but large curves may be associated with adverse long-term health outcomes in later adulthood, including an increased risk for shortness of breath with curves greater than 50°, diminished lung volumes with curves greater than 70°, and more impaired pulmonary function with curves greater than 100°.[17]

Screening may detect scoliosis earlier than it would be detected clinically. Generally accepted management in the United States includes observation for mild curves, brace treatment for moderate curves, and surgery for curves that progress to 50° or more (Box).[6] In some countries, exercise therapy is recommended for mild curves.

In 2004, the US Preventive Services Task Force (USPSTF) recommended against routine screening of asymptomatic adolescents for AIS (D recommendation).[19] The purpose of this systematic review was to update the previous evidence review to help the USPSTF update their recommendation.

## Methods

### Scope of Review

This review addressed 6 key questions (KQs) (**Figure 1**): whether AIS screening improves health outcomes in childhood or adulthood (KQ1), the accuracy of screening for AIS (KQ2), whether treatment of AIS improves health outcomes in childhood or adulthood (KQ3), the association between severity of spinal curvature in adolescence and health outcomes in adulthood (KQ4), the harms of screening for AIS (KQ5), and the harms of treating AIS (KQ6). Methodological details, including search strategies, inclusion criteria, excluded studies, and detailed results are publicly available in the full evidence report.[21]

### Data Sources and Searches

The literature search included PubMed, Cochrane Central Register of Controlled Trials, Ovid MEDLINE, ERIC (Eric.ed.gov), and CINAHL (Cumulative Index to Nursing and Allied Health Literature) (eMethods in the Supplement). The search was limited to articles published from January 1966 to October 20, 2016. Database searches were supplemented by a review of reference lists from recent and relevant systematic reviews, as well as a review of relevant ongoing trials in ClinicalTrials.gov and the World Health Organization International Clinical Trials Registry Platform.

After October 2016, ongoing surveillance continued through article alerts and targeted searches of a subset of core clinical journals identified by the USPSTF[20] to identify major studies published in the interim that may affect the conclusions or understanding of the evidence and therefore the related USPSTF recommendation. The last surveillance was conducted on July 24, 2017, and identified no new studies.

### Study Selection

Two reviewers independently reviewed 8230 titles and abstracts and 1088 articles against prespecified inclusion criteria, resolving discrepancies through consensus. For screening questions (KQ1, KQ2, and KQ5), the population of interest was asymptomatic children aged 10 to 18 years screened using any objectively measured screening test, most commonly the forward bend test (Box). Studies not conducted in the general population or in primary care settings were excluded from this review. For treatment questions (KQ3 and KQ6), inclusion criteria were studies of children and adolescents aged 10 to 18 years diagnosed with AIS with a Cobb angle of 10° to 50° at detection, since children with curves greater than 50° are likely to be detected clinically and therefore are not likely to be candidates for screening. Eligible treatments included multiple types of braces (Box), exercise treatment, and surgery. For all KQs, included study designs were randomized clinical trials (RCTs), nonrandomized trials, cohort studies, and registry-based observational studies. For harms questions (KQ5 and KQ6), case series and case-control studies were also included. For KQ4, only studies with outcomes collected in both adolescence and adulthood were included.

### Data Extraction and Quality Assessment

Key elements of included studies were abstracted into evidence tables tailored for each KQ and for specific study designs. The abstracted data included setting and population (eg, country, age, sex, race/ethnicity, maturity of population), screening and treatment details, reference standard or comparator details (if applicable), length of follow-up, and outcomes (eg, accuracy, benefits, harms). One reviewer completed primary data abstraction, and a second reviewer checked all data for accuracy and completeness.

Each study was assigned a final quality rating of good, fair, or poor based on design-specific criteria[20] (eTable 1 in the Supplement). In general, a good-quality study met all quality criteria. A fair-quality study failed to meet at least 1 criterion but had no known issue that would invalidate its results. Disagreements between investigators were resolved by discussion. Studies rated as poor quality were excluded if there was a major risk of bias (eg, evidence of selection bias or confounding, attrition greater than 40%, differential attrition higher than 20%, and not accounting for missing data) that could invalidate the results.

### Data Synthesis and Analysis

Results were synthesized in narrative format, and summary tables were used to compare results across different studies. For KQ2 (accuracy), values were calculated from data provided where possible. Because of the limited number of included studies for each key question, combined with the heterogeneity between study populations and outcomes, no pooling or meta-analyses were conducted. A standardized summary of evidence table was used to summarize the overall strength of evidence for each KQ.

Box. Glossary

**Adolescent idiopathic scoliosis (AIS):** Spinal curvature of greater than 10° Cobb angle presenting at 10 years or older and of unknown etiology. Increasingly recognized as a 3-dimensional deformity, often with a rotational component.

**Angle of trunk rotation (ATR)**: Measurement of trunk rotation according to a scoliometer. The Scoliosis Research Society (SRS) recommends an ATR of 5° to 7° as a threshold for referral for radiography.[1]

**Cobb angle**: Measure, in degrees, of lateral spinal curvature.[2] Requires radiographs for measurement.

**Skeletal maturity**: Occurs at the end of adolescence. Typically defined by a Risser sign of 4 or greater in female patients or 5 in male patients.

**Risser sign**: The stage of ossification of the iliac apophysis as seen on radiograph; this is measured on a scale of 1 to 5, with 5 indicating the full ossification seen in developmentally mature adolescents and adults.

**Forward bend test (FBT)**: The most commonly used screening test in the United States. A noninvasive screening procedure in which a person bends forward at the waist until the spine is parallel to the horizontal plane and the examiner checks the back for spinal asymmetry. The FBT is used in most school-based scoliosis screening programs. It can be used with or without a scoliometer.

**Scoliometer**: A handheld, noninvasive device placed on a patient's back during a forward bend test to measure ATR.

**Moiré topography**: A specialized device that projects contour lines onto a person's back; a photograph is then taken of the projection. An examiner counts the number of asymmetric contour lines.[3] Persons with 2 or more asymmetric Moiré fringes often are referred for radiography.[4] This screening modality is used infrequently in the United States.

**Brace treatment**: Brace treatment is not intended to correct curvature but rather to slow or halt curve progression; bracing therefore is indicated primarily for skeletally immature patients (Risser sign, 0-2) at high likelihood of rapid curve progression. Braces are typically worn until skeletal maturity. Braces fall into 3 general categories: full-time rigid bracing, nighttime rigid bracing, and soft bracing. Brace selection is based on curve location and characteristics and on the anticipated tolerance of the patient.[5]

**Full-time rigid bracing**: Most rigid braces are prescribed for use 20 to 24 hours per day.[6-8] Rigid braces include thoracolumbosacral orthotic (TLSO) rigid braces and cervical TLSO (CTLSO) braces. The Boston brace is the most commonly used TLSO is the United States. The CTLSO braces, like the Milwaukee brace, are most commonly used for thoracic curves with an apex above T8 or for double curves.

**Nighttime rigid bracing**: Rigid braces typically worn while sleeping.

**Soft bracing**: Adjustable, flexible, and noninvasive braces.

**Surgical treatment**: Spinal surgery to correct spinal curve is recommended for those with Cobb angles of 40° to 50°, depending on developmental maturity and type of curve.

**SOSORT guidelines**: The International Scientific Society on Scoliosis Orthopedic and Rehabilitation Treatment (SOSORT) recommends the following treatments based on Cobb angle. However, individual treatment may vary depending on speed of progression and remaining skeletal growth.

- <20°: Observation
- 20°-25°: Observation or brace
- 26°-45°: Brace
- 46°-50°: Brace or surgery
- >50°: Surgery

The strength of the overall body of evidence was graded for each key question using the Evidence-based Practice Center approach,[22] which is based on a system developed by the Grading of Recommendations Assessment, Development and Evaluation Working Group.[23] This summary of evidence table includes the number and design of included studies, summary of findings by outcome, consistency or precision of results, reporting bias, summary of study quality, limitations of the body of evidence, and applicability of the findings.

## Results

After review of 8230 abstracts and 1088 full-text articles (**Figure 2**), 14 studies published in 26 articles were included (N = 448 276) (**Table 1**). Seven studies (13 articles; n = 447 243) met inclusion criteria for screening accuracy (KQ2), 7 studies (9 articles; n = 835) for the benefits of treatment (KQ3), 1 study (2 articles; n = 242) for the harms of treatment (KQ6), and 2 studies (5 articles; n = 339) for long-term outcomes (KQ4). No studies met inclusion criteria for the effect of AIS screening on long-term health outcomes (KQ1) or on the harms of screening (KQ5).

### Screening

**Key Question 1.** Does screening for adolescent idiopathic scoliosis improve (a) health outcomes and (b) the degree of abnormal spinal curvature in childhood or adulthood?

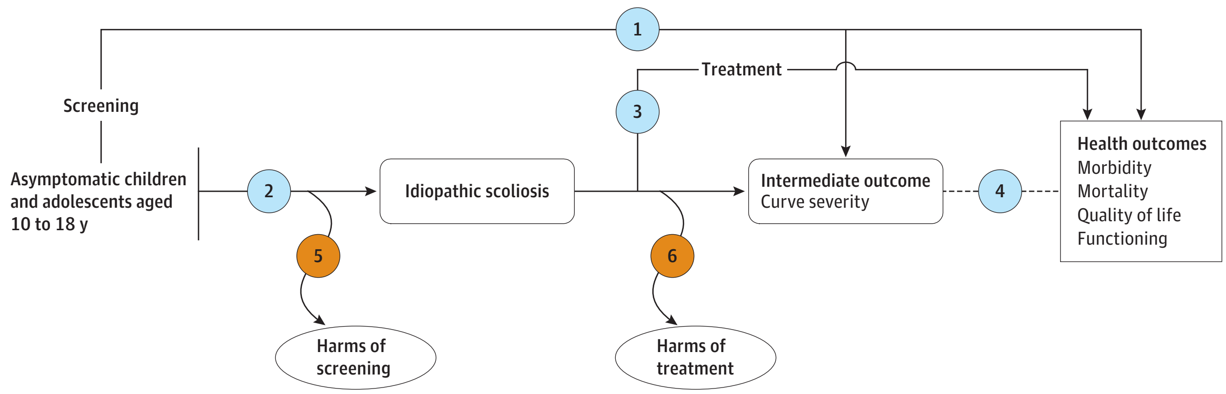
No RCTs or nonrandomized trials met inclusion criteria for evaluating the effect of screening for AIS on severity of curvature or adult health outcomes compared with no screening.

**Key Question 2.** What is the accuracy of screening for adolescent idiopathic scoliosis?

Seven fair-quality prospective cohort studies of screening programs (13 articles)[3,24-35] including 447 243 adolescents met inclusion criteria. Six of the 7 programs were conducted in school settings,[24,27,28,31,32,35] and there was heterogeneity in the screening tests used and in the training of the practitioners conducting screening. Five of 7 studies reported results of a single screening episode; 2 reported cumulative results of multiple years of repeated screening. Three of the 7 studies included some follow-up data on children who screened negative.[24,25,27] Consistent with previous estimates,[6,12,13] the included screening studies suggest an AIS prevalence ranging from 1.2% to 3.5%.[24,25,27]

Screening accuracy increased with the number of screening tests used (**Table 2**). Sensitivity and specificity were highest (93.8% and

Figure 1. Analytic Framework and Key Questions




Key questions

1 Does screening for adolescent idiopathic scoliosis improve:
a. Health outcomes?
b. The degree of abnormal spinal curvature in childhood or adulthood?

2 What is the accuracy of screening for adolescent idiopathic scoliosis?

3 Does treatment of adolescent idiopathic scoliosis that has a Cobb angle of less than 50° at diagnosis improve:
a. Health outcomes?
b. The degree of abnormal spinal curvature in childhood or adulthood?

4 What is the association between severity of spinal curvature in adolescence and health outcomes in adulthood?

5 What are the harms of screening for adolescent idiopathic scoliosis?

6 What are the harms of treatment of adolescent idiopathic scoliosis that has a Cobb angle of less than 50° at diagnosis?

Evidence reviews for the US Preventive Services Task Force (USPSTF) use an analytic framework to visually display the key questions that the review will address to allow the USPSTF to evaluate the effectiveness and safety of a preventive service. The questions are depicted by linkages that relate interventions and outcomes. A dashed line indicates a relationship between an intermediate outcome and a health outcome that is presumed to describe the natural progression of the disease. Further details are available in the USPSTF procedure manual.[20]

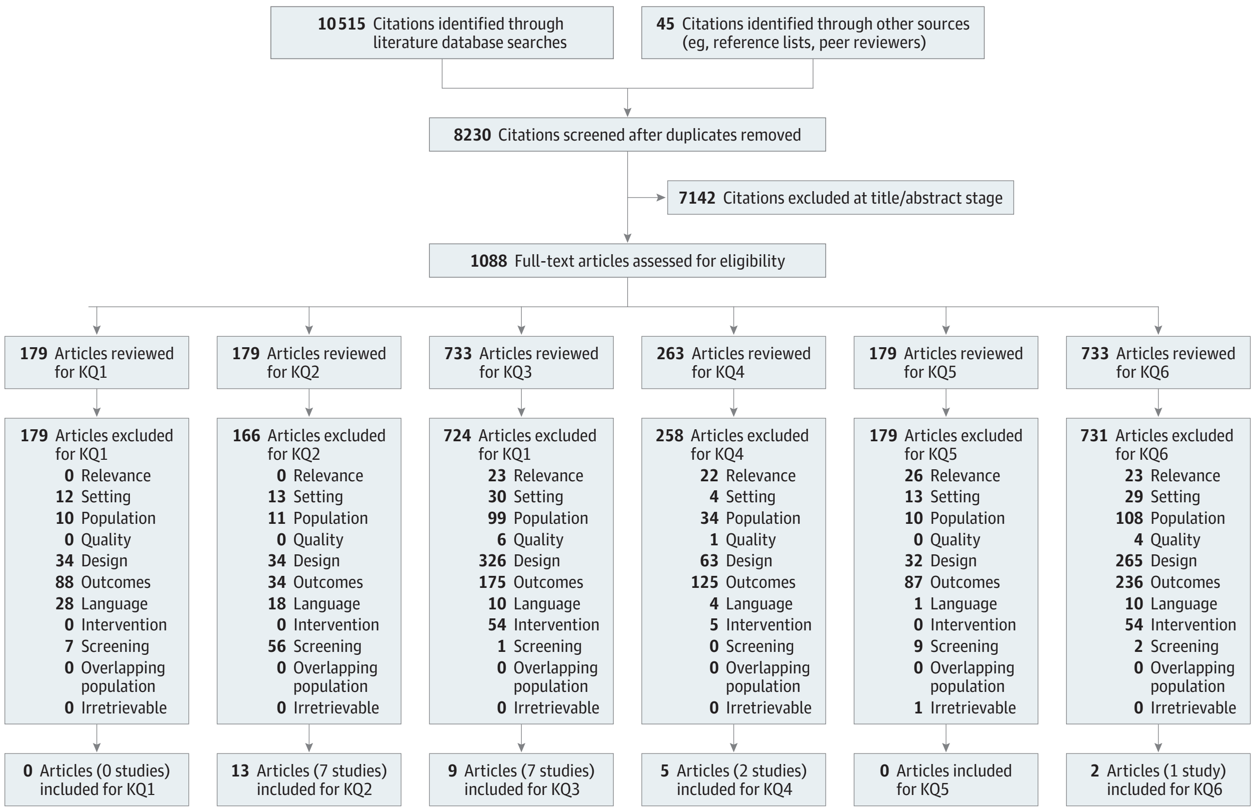
99.2%), predictive value was highest (81.0%), and false-positive rates were lowest (0.8%; 6.2% false-negative) in a clinic-based screening program using forward bend test, scoliometer, and Moiré topography screening (n = 306 082)[25]; accuracy was lower (71.1% sensitivity, 97.1% specificity, 2.9% false-positive, 28.9% false-negative) in a US-based study of forward bend test with scoliometer (n = 2242).[24] Sensitivity for single-modality screening in a school-based program screening children 8 years and older (n = 2700)[27] ranged from 84.4% for forward bend test alone to 100% for Moiré screening. False-positive rates ranged from 0.8%[25] to 21.5% [27]; false-negative rates ranged from 0% for Moiré screening[27] to 15.6% for forward bend test alone,[27] with 28.9% for forward bend test with or without scoliometer.[24] Positive predictive value estimates ranged from 29.3%[24] to 54.1% for forward bend test plus scoliometer[28] and ranged from 5.0% to 17.3% for a single screening modality[27] to 81.0% for forward bend test with scoliometer and Moiré screening.[25]

Two of 7 studies provided data comparing the degree of curvature in children with screen-identified scoliosis with that in those with false-negative screening results and later scoliosis diagnosis.[24,25] In a US-based study (n = 2242), distributions of curve were similar for children detected through school-based screening compared with those detected clinically.[24] However, in a Hong Kong–based, multitiered screening program (n = 306 082), curve distributions in screen-detected cases tended to be a lower degree of curvature (50.9% of the screen-detected vs 26.2% of the false-negative population had curves of 10° to 19°).[3,25,26] In the 5 studies with data on screen-detected cases only (n = 138 919),[27,28,31,32,35] the majority of cases detected were at Cobb angles of less than 20°, a level at which expectant management may be the most common treatment.

## Effects of Interventions on Health Outcomes

**Key Question 3.** Does treatment of adolescent idiopathic scoliosis that has a Cobb angle of less than 50° at diagnosis improve (a) health outcomes and (b) the degree of spinal curvature in childhood or adulthood?

Figure 2. Literature Search Flow Diagram




All eligible full-text articles could be reviewed for more than 1 key question (KQ).

Seven studies (9 articles; n = 835) on the benefits of treatment met inclusion criteria; this included 2 RCTs, 2 nonrandomized trials, a prospective cohort study, a retrospective cohort study, and a study that combined an RCT and a prospective cohort study.[28,36-43] Five studies (7 articles)[28,36-41] of 651 adolescents examined the association between bracing treatment and curve progression. Three brace studies (an RCT, a nonrandomized trial, and a retrospective cohort study) were of fair quality,[28,36,37] and 2 brace studies (a prospective cohort and the combined RCT and prospective cohort study) were of good quality.[38,40] Two studies[42,43] (1 good-quality RCT[42] and 1 fair-quality nonrandomized trial[43]) of 184 adolescents examined the benefits of exercise treatment.

## Brace Treatment

Studies defined treatment outcomes either as absolute increase in curvature (measured by Cobb angle)[28,36,37,40]; progression of curve past a defined number of degrees (usually 5° to 10°) during the study; or progression of curve to a threshold at which bracing treatment was considered failed, typically past 45° to 50° Cobb angle, when surgery may be considered.[28,36-38] One study, the combined RCT and prospective cohort study, presented dose-response data on the association between daily hours of brace wear and curve progression.[38,39] Most included studies reported on the proportion of participants whose curves met certain thresholds; only 1 reported Cobb angle both before and after treatment. Four prospective controlled studies (n = 587) found evidence for benefit of bracing treatment on curve progression compared with observed controls (eTable 2 in the Supplement).[36-38,40]

Three of 4 studies that evaluated absolute change in curvature in braced vs observed populations reported results favoring brace treatment (n = 345).[36,37,40] Three prospective controlled studies (n = 345)[36,37,40] found an association between bracing and slowing curve progression of 5° or 6°; 1 nonrandomized trial (n = 37)[37] and 1 retrospective cohort study (n = 64)[28] showed limited differences for progression of 10° or more between braced and observed groups.

Four studies (n = 411) evaluated the progression of curvature past an absolute threshold at which bracing treatment was considered as having failed.[28,36-38] The 1 study that combined an RCT and prospective cohort study (n = 242) demonstrated a significant benefit associated with bracing.[38,39] The single RCT of bracing (n = 68) suggested lesser progression in the braced group, but significance was not reported[36]; 2 smaller studies, a nonrandomized trial and a retrospective cohort study (n = 101), found similar results between braced and control populations.[28,37]

The largest included bracing study (n = 242) was the good-quality, international RCT combined with a prospective cohort study called the Bracing in Adolescent Idiopathic Scoliosis Trial (BRAIST), which assessed the association between bracing

Table 1. Characteristics of All Included Studies, by Key Question

| Source (Country) | Quality | Study Design | No. | Age, Mean (SD), y | Female, No. (%) | Screening Test or Treatment | Outcomes Reported |
|---|---|---|---|---|---|---|---|
| **Screening Studies (KQ2)** | | | | | | | |
| Screening programs with follow-up of screen-negative children | | | | | | | |
| Yawn et al,[24] 1999 (United States) | Fair | Prospective cohort | 2242 | NR (US grades 5-9) | NR | FBT ± scoliometer[a] | PPV<br>Sensitivity, specificity<br>False-positive rate<br>False-negative rate<br>Prevalence of AIS |
| Fong et al,[25] 2015<br>Lee et al,[26] 2010<br>Luk et al,[3] 2010<br>(Hong Kong) | Fair | Prospective cohort | 306 082[b,c] | NR (Hong Kong fifth grade or ≥10 y old) | NR | FBT + scoliometer ± Moiré topography | PPV<br>Sensitivity, specificity<br>False-positive rate<br>False-negative rate<br>Prevalence of AIS |
| Karachalios et al,[27] 1999 (Greece [Samos Island]) | Fair | Prospective cohort | 2700 | Range, 8-16 | NR | FBT<br>Scoliometer<br>Moiré topography<br>Humpometer[d] | PPV<br>Sensitivity, specificity<br>False-positive rate<br>False-negative rate<br>Prevalence of AIS |
| Screening programs with no follow-up of screen-negative children | | | | | | | |
| Goldberg et al,[28] 1993<br>Goldberg et al,[29] 1993<br>Goldberg et al,[30] 1995<br>(Ireland) | Fair | Prospective cohort | 8669[e] | 12.9 (1.4) | 8669 (100) | FBT + scoliometer | PPV<br>Screening yield |
| Wong et al,[31] 2005 (Singapore) | Fair | Prospective cohort | 40 649[b,f] | 9-10:<br>16 755 (41.2%)[b]<br>11-12:<br>18 101 (44.5%)[b]<br>13-14:<br>5793 (14.3%)[b] | 20 453 (50.3)[b,f] | FBT + scoliometer | PPV<br>Screening yield |
| Adobor et al,[32] 2011 (Norway) | Fair | Prospective cohort | 4000 | 12-13 | NR | FBT + scoliometer | PPV<br>Screening yield |
| Soucacos et al,[33] 1997<br>Soucacos et al,[34] 1998<br>Soucacos et al,[35] 2000<br>(Greece [Northwestern and Central]) | Fair | Prospective cohort | 82 901 | 12.4 (range, 9-14) | 40 962 (49.4) | FBT + plane/level | PPV<br>Screening yield |
| **Treatment Studies (KQ3, KQ6)[g]** | | | | | | | |
| Bracing studies | | | | | | | |
| Coillard et al,[36] 2014[h] (Canada) | Fair | RCT | 68<br>Intervention:32<br>Control: 36 | Intervention:<br>12.0 (2)<br>Control: 12.0 (2) | Intervention: 22 (85)[i]<br>Control: 18 (86)[i] | Spine-Cor brace | Curve progression |
| Wiemann et al,[37] 2014 (United States) | Fair | Nonrandomized trial | 37<br>Intervention: 21<br>Control: 16 | Intervention:<br>12.0 (1.3)<br>Control: 11.9 (1.2) | 37 (100) | Charleston bending brace | Curve progression |
| BRAIST[g]<br>Weinstein et al,[38] 2013<br>Weinstein et al,[39] 2013<br>(United States, Canada) | Good | Combination of RCT and cohort study | 242[j]<br>Intervention: 146<br>Control: 96 | Intervention:<br>12.7 (1.0)<br>Control:12.7 (1.2) | Intervention:<br>135 (92)<br>Control: 86 (90) | Rigid TLSO (various) braces | Curve progression<br>Quality of life<br>Back pain<br>Harms of treatment |

*(continued)*

Table 1. Characteristics of All Included Studies, by Key Question (continued)

| Source (Country) | Quality | Study Design | No. | Age, Mean (SD), y | Female, No. (%) | Screening Test or Treatment | Outcomes Reported |
|---|---|---|---|---|---|---|---|
| SRS Bracing Study<br>Nachemson and Peterson,[40] 1995<br>Peterson and Nachemson,[41] 1995<br>(Sweden, United States, United Kingdom, Canada) | Good | Prospective cohort | 240<br>Intervention: 111<br>Control: 129 | Mean, NR (range, 10-15) | 240 (100) | Boston brace | Curve progression |
| Goldberg et al,[28] 1993<br>(United States, Ireland) | Fair | Retrospective cohort | 64<br>Intervention: 32<br>Control: 32 | Intervention: 13.1 (0.8)<br>Control: 13.1 (0.8) | 64 (100) | Boston brace | Curve progression |
| Exercise studies | | | | | | | |
| Monticone et al,[42] 2014<br>(Italy) | Good | RCT | 110<br>Intervention: 55<br>Control: 55 | Intervention: 12.5 (1.1)<br>Control: 12.4 (1.1) | Intervention: 39 (70.9)<br>Control: 41 (74.5) | Active self-correction exercises | Spinal curve<br>ATR<br>Pain<br>Function<br>Self-image<br>Mental health |
| Negrini et al,[43] 2008<br>(Italy) | Fair | Nonrandomized trial | 74<br>Intervention: 35<br>Control: 39 | Intervention: 12.7 (2.2)<br>Control: 12.1 (2.1) | Intervention: 25 (71.4)<br>Control: 27 (69.2) | Active self-correction exercises | Cobb angle<br>ATR |
| **Long-term Follow-up Studies (KQ4)** | | | | | | | |
| SRS Bracing Cohort<br>Danielsson et al,[44] 2010<br>Danielsson et al,[45] 2012<br>(Sweden) | Fair | Retrospective cohort | 77<br>Observation: 40<br>Brace: 37 | Observation: 14.0 (0.9)[k]<br>Brace: 13.4 (1.2)[k] | Observation: 40 (100)<br>Brace: 37 (100) | Boston brace until skeletal maturity | SRS-22<br>SF-36<br>Spinal Appearance Questionnaire |
| Goteborg Cohort<br>Danielsson et al,[46] 2001<br>Danielsson and Nachemson,[47] 2001<br>Pehrsson et al,[48] 2001<br>(Sweden) | Fair | Retrospective cohort | 262<br>Brace: 116<br>Surgery: 146 | Brace: 14.4 (1.4)[k]<br>Surgery: 15.0 (1.8)[k] | Brace: 111 (95.7)<br>Surgery: 136 (93.1) | Boston or Milwaukee brace until skeletal maturity<br>Surgical treatment with Harrington distraction and fusion | SF-36<br>PGWB<br>ODI<br>Childbearing and pregnancy outcomes (n = 247)<br>Pulmonary outcomes (n = 251) |

Abbreviations: AIS, adolescent idiopathic scoliosis; ATR, angle of trunk rotation; BRAIST, Bracing in Adolescent Idiopathic Scoliosis Trial; FBT, forward bend test; KQ, key question; NR, not reported; ODI, Oswestry Disability Index; PGWB, Psychological General Well-Being Index; PPV, positive predictive value; RCT, randomized clinical trial; SF-36, 36-Item Short Form Health Survey; SRS, Scoliosis Research Society; SRS-22, Scoliosis Research Society 22-Item Questionnaire; TLSO, thoracolumbosacral orthotic.

[a] Rochester Screening Program used FBT only (1984-1985) before FBT + scoliometer (1986-1991).

[b] Values were not provided in the article(s) and were calculated.

[c] Does not include 62 students diagnosed with nonidiopathic scoliosis by age 19 years.

[d] A noninvasive screening tool consisting of a series of movable strips placed along a person's back perpendicular to the spine. The examiner locks the strips into place, then transfers the resulting contour lines to graph paper.[49]

[e] Does not include 17 who did not show up for a reexamination and were excluded.

[f] Excludes ages 6 to 7 years (n = 32 050).

[g] The BRAIST trial was included for both KQ3 and KQ6.

[h] Recruitment in Coillard 2014 and BRAIST were terminated early because of evidence of benefit favoring bracing.

[i] Represents percentage female for those who completed the study (n = 47 [26 intervention, 21 control]).

[j] 47.9% of population from RCT.

[k] Mean age at start of treatment.

Table 2. Results From Prospective Cohort Studies on Accuracy of Scoliosis Screening (KQ2)

| 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[a] |
|---|---|---|---|---|---|---|---|---|
| **Screening Programs With Follow-up of Screen-Negative Children** | | | | | | | | |
| Yawn et al,[24] 1999 (United States) | 2242 | FBT ± scoliometer (annual over multiple years)[b] | 29.3 (20.3-39.8)[c,d] | 71.1 (54.1-84.6)[d] | 97.1 (96.3-97.7)[c,d] | 2.9[c,d] | 28.9[d] | 1.7[d] |
| Fong et al,[25] 2015<br>Lee et al,[26] 2010<br>Luk et al,[3] 2010<br>(Hong Kong) | 306 082[d,e] | FBT + scoliometer ± Moiré topography (biennial or more often) | 81.0 (80.3-81.7)[c,d] | 93.8 (93.3-94.3)[d] | 99.2 (99.2-99.2)[c,d] | 0.8[c,d] | 6.2[d] | 3.5[c,d] |
| Karachalios et al,[27] 1999 (Greece [Samos Island]) | 2700 | FBT (one-time) | 17.3 (11.7-24.2)[d] | 84.4 (67.2-94.7)[d] | 95.2 (94.3-95.9)[d] | 4.8[d] | 15.6[d] | 1.2[d] |
| | 2700 | Scoliometer (one-time) | 5.3 (3.6-7.6)[d] | 90.6 (75.0-98.0)[d] | 80.7 (79.1-82.1)[d] | 19.3[d] | 9.4[d] | 1.2[d] |
| | 2700 | Moiré topography (one-time) | 7.6 (5.3-10.6)[d] | 100.0 (84.2-100)[d] | 85.4 (84.0-86.7)[d] | 14.6[d] | 0[d] | 1.2[d] |
| | 2700 | Humpometer (one-time)[f] | 5.0 (3.4-7.0)[d] | 93.8 (79.2-99.2)[d] | 78.5 (76.9-80.0)[d] | 21.5[d] | 6.3[d] | 1.2[d] |
| **Screening Programs With No Follow-up of Screen-Negative Children** | | | | | | | | |
| Goldberg et al,[28] 1993<br>Goldberg et al,[29] 1993<br>Goldberg et al,[30] 1995<br>(Ireland) | 8669[g] | FBT + scoliometer (one-time) | 54.1 (40.8-66.9)[d] | NR | NR | NR | NR | 0.4[d,h] |
| Wong et al,[31] 2005 (Singapore) | 40 649[d,i] | FBT + scoliometer (one-time) | 41.2 (37.4-45.1)[d,i] | NR | NR | NR | NR | 0.7[d,h,i] |
| Adobor et al,[32] 2011 (Norway) | 4000 | FBT + scoliometer (one-time) | 36.7 (24.6-50.1)[d] | NR | NR | NR | NR | 0.6[d,h] |
| Soucacos et al,[33] 1997<br>Soucacos et al,[34] 1998<br>Soucacos et al,[35] 2000<br>(Greece [Northwestern and Central]) | 82 901 | FBT + plane/level (one-time) | 34.3 (32.9-35.8)[d] | NR | NR | NR | NR | 1.7[d,h] |

Abbreviations: AIS, adolescent idiopathic scoliosis; FBT, forward bend test; KQ, key question; NR, not reported.

[a] Calculated as number of disease positives (true positives + false negatives) divided by the total number screened.

[b] Rochester Screening Program used FBT only (1984-1985) before FBT plus scoliometer (1986-1991).

[c] Assumes those lost to follow-up tested false positive.

[d] Values were not provided in the article(s) and were calculated.

[e] Does not include 62 students diagnosed with nonidiopathic scoliosis by age 19 years.

[f] A noninvasive screening tool consisting of a series of movable strips placed along a person's back perpendicular to the spine. The examiner locks the strips into place, then transfers the resulting contour lines to graph paper.[49]

[g] Does not include 17 who did not show up for a reexamination and were excluded.

[h] Screening yield of AIS greater than 10° Cobb angle; yield calculated as number of true positives divided by the total number screened.

[i] Excludes ages 6 to 7 years (n = 32 050).

18 hours per day and preventing progression of Cobb angle past 50°.[38,39] This study planned to follow up participants through skeletal maturity but was terminated early by the data and safety monitoring board because of treatment benefit in favor of bracing. In the as-treated analysis, which included both the randomized and patient-preference cohorts, 41 of 146 braced participants (28%) had progression of Cobb angle past 50°, compared with 50 of 96 (52%) untreated participants. The odds ratio for the study definition of a successful outcome (skeletal maturity without progression of Cobb angle past 50°) was 1.93 (95% CI, 1.08-3.46), adjusted for duration of follow-up and propensity score quintile (used to control for potential selection bias in the nonrandomized cohort). Data from the intention-to-treat analysis (RCT cohort) likewise showed a statistically significant association between bracing and reduced curve progression, with progression past 50° in 25% of braced participants and 58% of untreated participants (the unadjusted odds ratio for a successful outcome was 4.11 [95% CI, 1.85-9.16]). The number needed to treat to prevent 1 case of curve progression past 50° was 3.0 (95% CI, 2.0-6.2), and the reduction in relative risk with bracing was 56% (95% CI, 26%-82%). This trial was the only one reporting quality-of-life outcomes associated with bracing; outcomes were similar between treatment groups (eTable 3 in the Supplement).

Cobb angle in adulthood was assessed in 1 prospective cohort study of bracing,[40,41] which suggested little progression in adulthood in either treated or observed individuals with curves of moderate magnitude. Seventy-seven of the original 106 adolescent female patients who had been enrolled at 2 of the centers in the Scoliosis Research Society bracing cohort were reevaluated a mean of 16 years after skeletal maturity (mean age, 32 years).[44,45] Mean Cobb angles at maturity in this cohort were similar in both the observed and braced groups (30.6° in observed participants, 27.7° in braced participants; $P = .07$). Between skeletal maturity and adult follow-up, mean Cobb angle had increased by a mean of 4.4° (SD, 4.1°) in observed patients and by a mean of 6.4° (SD, 5.8°) in braced patients. Only 3 of 40 observed individuals (7.5%) and 2 of 37 braced individuals (5.4%) had progression of the curve past 45° at the time of follow-up ($P > .99$).

### Exercise Treatment

In 1 good-quality RCT (n = 110)[42] and 1 fair-quality nonrandomized trial (n = 74)[43] of tailored physiotherapeutic scoliosis-specific exercise, the intervention group experienced significant improvement compared with a generic-exercise control group at 12-month follow-up (eTable 4 and eTable 5 in the Supplement). In the RCT (n = 110), there was a favorable reduction in Cobb angle of 4.9° in the intervention group compared with the control group's unfavorable increase of 2.8° ($P < .001$). Quality-of-life measures were improved at 12 months in the intervention group, compared with stable or slightly improving measures in the control group.[42] By the end of the nonrandomized trial's 12-month treatment period, the intervention group had experienced a favorable decrease in mean magnitude of all curves of 0.67°, compared with the control group's unfavorable progression of 1.38° ($P < .05$).[43]

### Surgical Treatment

No studies of surgical treatment in adolescents with a Cobb angle less than 50° at diagnosis met inclusion criteria.

## Association Between Spinal Curvature and Health Outcomes

**Key Question 4.** What is the association between severity of spinal curvature in adolescence and health outcomes in adulthood?

Two fair-quality retrospective cohort studies (5 articles)[44-48] of 339 individuals with AIS followed up in adulthood met inclusion criteria. Both included studies were retrospective observational long-term follow-up analyses of individuals with AIS diagnosed during adolescence. One study[44,45] evaluated a cohort of 77 adults who were either braced or observed during adolescence as part of a bracing study; the other[46-48] included various subsets of a cohort of 283 persons with AIS who had been consecutively referred to a regional center for bracing or surgical treatment during adolescence, 262 of whom were assessed in adulthood. Follow-up occurred at least 11 years after skeletal maturity in the smaller cohort and at least 20 years after treatment in the larger cohort.

No included studies reported health outcomes data stratified by degree of curvature at skeletal maturity; therefore, no included studies directly address the key question as worded. Instead, the included studies provide insight into adult health outcomes stratified by adolescent treatment regimen received, which sometimes can vary by curve severity. Both general and scoliosis-specific quality-of-life measures (36-Item Short Form Health Survey; Scoliosis Research Society 22-Item Questionnaire) were similar between observed and braced participants at adult follow-up in 1 retrospective cohort study (n = 77).[44,45] In the other retrospective cohort study (n = 262), Oswestry Disability Index scores, general well-being, self-esteem, social activity, pulmonary outcomes, and childbearing and pregnancy outcomes were similar in adulthood in people braced or surgically treated in adolescence (Table 3).[46-48] However, braced participants rated their body appearance as more distorted than did untreated participants.[45] Braced individuals also recalled experiencing a negative effect on their life during the treatment period compared with those treated surgically.[46]

## Harms of Interventions

**Key Question 5.** What are the harms of screening for adolescent idiopathic scoliosis?

No studies on harms of screening met inclusion criteria. False-positive rates ranged from 0.8% for clinic-based forward bend test with scoliometer and Moiré screening[25] to 21.5% for hump assessment alone[27] (reported in KQ2), although the harms associated with false-positive screening are unclear.

**Key Question 6.** What are the harms of treatment of adolescent idiopathic scoliosis that has a Cobb angle of less than 50° at diagnosis?

Harms of bracing were reported in 1 good-quality combination of an RCT with a prospective study (n = 242).[38,39] The most frequently reported nonserious adverse events were those involving the skin under the brace; there were 12 reports of such symptoms in the 146 braced participants compared with zero reports in the 96 observed participants. There were 12 reports of nonback body pain in the braced group and 2 such reports in observed group. One of the 146 braced participants reported a serious adverse event (anxiety and depression requiring hospitalization).

Table 3. Health and Quality-of-Life Outcomes in Adulthood From Retrospective Long-term Follow-up Studies of AIS Cohorts Treated in Adolescence (KQ4)

| | SRS Bracing Cohort[a] Danielsson et al,[44] 2010 Danielsson et al,[45] 2012[c] | | | Goteborg Cohort[b] Danielsson et al,[46] 2001 Danielsson and Nachemson,[47] 2001 Pehrsson and Danielsson,[48] 2001[d] | | |
|---|---|---|---|---|---|---|
| | Observed | Brace-Treated | *P* Value | Surgically Treated | Brace-Treated | *P* Value |
| No. of participants | 40 | 37 | | 146 | 116 | |
| AIS treatment received in adolescence | Observation only | Boston brace until skeletal maturity | | Surgery with Harrington distraction and fusion | Boston or Milwaukee brace until skeletal maturity | |
| Age at follow-up, mean (SD), y | 32.2 (1.2) | 32.4 (1.8) | NR | 39.7 (2.5) | 39.3 (2.2) | .31 |
| Cobb angle pretreatment, mean (SD) [range], degrees | 29.2 (3.0) [23-35] | 30.5 (3.2) [25-38] | .11 | 61.8 (13.2) [38-122] | 33.2 (9.6) [12-60] | <.001 |
| Cobb angle at skeletal maturity/end of treatment, mean (SD) [range], degrees | 30.6 (4.9) [21-42] | 27.7 (6.8) [14-42] | .07 | 33.1 (9.4) [12-65] | 29.7 (11.2) [0-58] | <.05[e] |
| Cobb angle at follow-up in adulthood, mean (SD) [range], degrees | 35.0 (6.5) [21-48] | 34.1 (7.7) [19-48] | .75 | 36.5 (9.7) [14-66] | 37.6 (14.7) [5-71] | .48 |
| Spinal Appearance Questionnaire scores in adulthood, mean (SD) [range][f] | 12.9 (4.4) [7-25] | 15.0 (4.6) [7-29] | .03 | NA | NA | NA |
| ODI scores in adulthood, mean (SD) [range][g] | NA | NA | NA | 8.3 (10) [0-50] | 7.6 (9.0) [0-36] | .49 |
| SF-36 scores in adulthood, mean (95% CI)[h] | | | | | | |
| Physical functioning | 94.5 (91.9-97.1) | 94.9 (92.1-97.1) | .80 | 85.8 (83.1-88.5) | 88.2 (85.5-90.9) | .22 |
| Role physical | 93.1 (87.3-98.9) | 91.9 (84.8-97.7) | .94 | 86.8 (81.9-91.7) | 82.8 (76.7-88.9) | NR |
| Bodily pain | 75.0 (67.4-82.5) | 68.1 (60.2-74.5) | .19 | 70.8 (66.5-75.1) | 71.5 (66.6-76.4) | .73 |
| General health | 83.7 (74.6-88.2) | 79.8 (75.1-83.6) | .15 | 75.1 (71.8-78.4) | 77.6 (74.3-80.9) | .49 |
| Vitality | 69.9 (63.3-76.1) | 68.2 (61.6-73.7) | .78 | 68.4 (65.1-71.7) | 63.1 (59.2-67.0) | NR |
| Social functioning | 91.9 (86.7-97.0) | 89.5 (83.3-94.6) | .34 | 90.7 (87.8-93.6) | 90.0 (86.7-93.3) | NR |
| Role emotional | 90.0 (82.5-97.5) | 86.5 (76.5-94.6) | .79 | 88.1 (83.6-92.6) | 89.1 (84.6-94.4) | NR |
| Mental health | 83.5 (78.9-88.1) | 81.3 (76.2-85.4) | .51 | 81.0 (78.5-83.5) | 80.8 (77.7-83.9) | NR |
| How did you experience the treatment period? No. (%) | | | | | | |
| Major positive effect on my life | NA | NA | NA | 37 (25.3) | 6 (5.1) | |
| Minor positive effect on my life | NA | NA | NA | 33 (22.6) | 8 (15.5) | |
| In no way affected my life | NA | NA | NA | 18 (12.3) | 17 (14.6) | <.001 |
| Minor negative effect on my life | NA | NA | NA | 37 (25.3) | 43 (37.1) | |
| Major negative effect on my life | NA | NA | NA | 21 (14.4) | 32 (27.6) | |

Abbreviations: AIS, adolescent idiopathic scoliosis; KQ, key question; NA, not assessed; NR, not reported; ODI, Oswestry Disability Index; SF-36, 36-Item Short Form Health Survey; SRS, Scoliosis Research Society.

[a] Study was of fair quality, conducted among 77 participants in 2 medical centers in Sweden from 1985-1989, with follow-up to 11 years or more postmaturity.

[b] Study was of fair quality, conducted among 262 participants in a university hospital in Sweden from 1968-1977, with follow-up to 20 years or more posttreatment.

[c] The SRS Bracing Cohort study also reported outcomes from the Scoliosis Research Society 22-Item Questionnaire; no significant differences were found between groups.

[d] The Goteborg study also reported outcomes from the Psychological General Well-Being Index (no correlation between angle of trunk rotation at follow-up and Psychological General Well-Being Index scores), pulmonary outcomes (no correlation between curve size after treatment and vital capacity or forced expiratory volume), and childbearing and pregnancy outcomes (no significant differences between groups for marital status, number of children, birthweight, or pregnancy complications).

[e] Reported in Danielsson 2001 article,[50] with n = 248 (139 surgical therapy; 109 brace therapy).

[f] Measures patient perceptions of spinal deformity and scored on a scale from 7 (least distorted) to 35 (most distorted). Scores were correlated with major curve size for all participants, with Spearman rank correlation rs = 0.40 ($P < .001$).

[g] Possible scores, 0 (best) to 100 (worst).

[h] Possible scores, 0 (worst) to 100 (best), scaled to population norm of 50.

## Discussion

This systematic review[21] was conducted to assist the USPSTF in updating its 2004 recommendation[19] on routine screening of asymptomatic adolescents for AIS. Fourteen unique studies were included, more than half of which (8 studies) were published since the previous USPSTF review.

**Table 4** summarizes the findings for this evidence review. Updated evidence suggests that AIS can be identified with forward bend test, scoliometer, or both, with radiologic confirmation, although estimates of predictive value and sensitivity are variable and the majority of individuals identified through screening will never require treatment. This review includes data from 3 prospective controlled bracing studies published since the 2004 evidence review, one of which was a large study (n = 242) conducted

Table 4. Summary of Evidence

| No. of Studies, No. of Observations (Study Design) | Summary of Findings by Outcome | Consistency/Precision | Reporting Bias | Overall Quality | Body of Evidence Limitations | EPC Assessment of Strength of Evidence | Applicability |
|---|---|---|---|---|---|---|---|
| **KQ1** | | | | | | | |
| No studies | NA | NA | NA | NA | NA | NA | NA |
| **KQ2** | | | | | | | |
| 7 studies (prospective cohort studies of screening programs [6/7 school-based]); n = 447 243 | FBT ± scoliometer (4 studies): Sensitivity (1 study), 71.1% Specificity (1 study), 97.1% PPV (4 studies), 29.3%-54.1% FBT + scoliometer + Moiré topography (1 study): Sensitivity, 93.8% Specificity, 99.2% PPV, 81.0% Single modality (1 study): Sensitivity, 84.4%-100% Specificity, 78.5%-95.2% PPV, 5.0%-17.3% | Inconsistent Imprecise | Undetected | Fair | Limited/ad hoc to no follow-up of screen-negative children; heterogeneity of screening modality and screening procedures; limited description of screening populations and subgroups | Low | Moiré topography and surgeon-conducted screening may not be feasible in US school-based screening programs |
| **KQ3: Benefits of Bracing** | | | | | | | |
| 1 study (RCT); n = 68 1 study (nonrandomized trial); n = 37 1 study (combination RCT and prospective cohort); n = 242 1 study (prospective cohort); n = 240 1 study (retrospective cohort); n = 64 | Curve progression: 4 prospective studies (1 RCT) suggest a benefit to bracing Dose-response: Evidence for dose-response relationship between hours of brace wear and curve progression in 1 study Quality of life: Similar at baseline and follow-up in intervention and control groups | Reasonably consistent Imprecise | Undetected | 3 Fair 2 Good | Higher-quality studies show benefit of bracing; smaller studies not powered to look at curve outcomes found nonsignificant results. Very limited data on QOL associated with bracing. | Moderate | Likely applicable to US settings; brace types in included studies all available in United States |
| **KQ3: Benefits of Exercise** | | | | | | | |
| 1 study (RCT); n = 110 1 study (nonrandomized trial); n = 74 | Curve progression: In 1 good-quality RCT, the intervention group had a favorable reduction in Cobb angle of 4.9° vs an unfavorable 2.8° progression in the control group. A smaller, fair-quality nonrandomized trial published earlier found similar results. QOL: Improved pain, function, self-image, and mental health; lack of improvement in control group | Reasonably consistent Imprecise | Undetected | 1 Good 1 Fair | Only 2 included studies; blinding of treatment allocation not possible | Low | Likely applicable to US setting given access to trained physiotherapist |
| **KQ3: Benefits of Surgery** | | | | | | | |
| No studies | NA | NA | NA | NA | NA | NA | NA |

*(continued)*

Table 4. Summary of Evidence (continued)

| No. of Studies, No. of Observations (Study Design) | Summary of Findings by Outcome | Consistency/Precision | Reporting Bias | Overall Quality | Body of Evidence Limitations | EPC Assessment of Strength of Evidence | Applicability |
|---|---|---|---|---|---|---|---|
| **KQ4** | | | | | | | |
| 2 studies (retrospective cohort); n = 339 | No direct evidence on association between curve at skeletal maturity and adult outcomes. However, quality of life, pulmonary, and pregnancy outcomes were similar for adults who had received observation, bracing, and surgery in adolescence. | Reasonably consistent<br>Imprecise | Undetected | 2 Fair | Small body of evidence, studies not designed to answer current KQ | Low | Limited; some obsolete treatments were included |
| **KQ5** | | | | | | | |
| No studies | NA | NA | NA | NA | NA | NA | NA |
| **KQ6: Harms of Bracing** | | | | | | | |
| 1 study (combination RCT and prospective cohort); n = 242 | Anxiety/depression requiring hospitalization: 1/146 in braced group vs 0/96 in control group; anxiety/depression: 3/146 in intervention group vs 1/96 in control group.<br>Skin problems on trunk more likely in braced group (12/146) vs control group (0/96); higher rate of nonback pain in braced group vs control group (12/146 vs 2/96).<br>Similar rates of abnormal breast development, neurologic symptoms, and gastrointestinal or respiratory symptoms in braced group vs control group. | NA (1 study) | Undetected | 1 Good | 1 study | Low | Likely applicable in US primary care setting |
| **KQ6: Harms of Surgery** | | | | | | | |
| No studies | NA | NA | NA | NA | NA | NA | NA |
| **KQ6: Harms of Exercise** | | | | | | | |
| No studies | NA | NA | NA | NA | NA | NA | NA |

Abbreviations: EPC, Evidence-based Practice Center; FBT, forward bend test; KQ, key question; NA, not applicable; PPV, positive predictive value; QOL, quality of life; RCT, randomized clinical trial.

at 25 sites in the United States and Canada. These studies suggest that brace treatment is associated with a decreased likelihood of curve progression before skeletal maturity, without significant short-term harms. Furthermore, limited new evidence suggests curves may respond similarly to physiotherapeutic, scoliosis-specific exercise treatment; if confirmed, this may represent a treatment option for mild curves before bracing is recommended.

Surgical treatment remains the standard of care for curves that progress to greater than 40° to 50°; however, there are no controlled studies of surgical vs nonsurgical treatment in individuals with lower degrees of curvature at AIS detection (which would best represent a screen-identified population). Although long-term observational studies suggest continued curve progression in adulthood is less likely for curves of smaller magnitude at skeletal maturity, direct evidence on the association between magnitude of curve at skeletal maturity and adult quality-of-life outcomes is lacking. Further, no direct evidence was found either for a benefit of universal AIS screening of adolescents on long-term health outcomes or for exposure-related or psychological harms of screening. Although several studies have suggested that radiation exposure over the course of management of and surveillance for scoliosis is associated with increased cancer risk in adulthood,[51-54] the effect of screening-only exposure was not reported in any included studies.

Limitations of the body of evidence include the lack of studies on screening approaches in targeted populations based on sex or other factors associated with likelihood of curve progression. Further, several studies found few adolescents willing to be randomized to a treatment group and therefore did not sufficiently accrue participants.[55,56] The lack of long-term outcomes data stratified by degree of curvature at skeletal maturity limits the ability to draw conclusions about the long-term clinical effect associated with the interruption of curve progression during adolescence.

Studies that prospectively enroll cohorts at AIS diagnosis or treatment for the purpose of long-term follow-up into adulthood would strengthen the body of evidence on the long-term effects of screening. Also needed are controlled trials of scoliosis screening programs that allow comparison of screened and nonscreened populations, different screening settings, personnel, and procedures. Ideally, screening results should be reported for all relevant populations, including female patients and children with a family history of scoliosis. Prospective, systematic collection of data on the potential harms of screening—including psychosocial effects and radiation exposure estimates for screened (as opposed to treated) populations—also is needed.

Because the utility of screening ultimately is determined by whether treatment of people with AIS identified through screening is effective in improving long-term health outcomes, the body of evidence also would be strengthened by additional good-quality studies of treatment, such as more prospective studies of exercise and brace treatment and studies on surgical treatment for people whose AIS was identified through screening. High-quality studies assessing the procedural and quality-of-life harms of screening and treatment also are needed.

### Limitations

Limitations of the review approach include exclusion criteria that resulted in a small body of evidence but one that reflects the best available studies in this field. The scope of this review was intentionally limited to individuals with curves less than 50° at detection to assess the evidence for a screening-relevant, primary care population. Studies without valid comparison groups and studies of surgical intervention without data on curve progression before surgery were excluded. Also excluded were a large number of studies with no comparison group, comparative effectiveness studies, longitudinal studies that did not report health outcomes in adulthood, studies in which screening was conducted by a single practitioner, and studies in which screening results were not objectively measured. Quality rating of studies—some of which were published as far back as 1966—further limited the body of evidence, as many were conducted before currently accepted quality measures and reporting standards were established. The decision to not pool or meta-analyze results based on heterogeneity of the included outcomes limited interpretation of single estimates of harm or benefit.

## Conclusions

Screening can detect AIS. Bracing and possibly exercise treatment can interrupt or slow progression of curvature in adolescence. However, there is little or no evidence on long-term outcomes for AIS treated in adolescence, the association between curvature at skeletal maturity and adult health outcomes, the harms of AIS screening or treatment, or the effect of AIS screening on adult health outcomes.

ARTICLE INFORMATION

**Accepted for Publication:** August 2, 2017.

**Author Contributions:** Dr Dunn had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
*Study concept and design:* All authors.
*Acquisition, analysis, or interpretation of data:* Dunn, Henrikson, Morrison, Blasi, Nguyen.
*Drafting of the manuscript:* Henrikson, Morrison, Blasi, Nguyen.
*Critical revision of the manuscript for important intellectual content:* All authors.
*Statistical analysis:* Dunn, Henrikson.
*Obtained funding:* Henrikson, Lin.
*Administrative, technical, or material support:* Dunn, Morrison, Blasi, Nguyen.
*Study Supervision:* Dunn, Henrikson, Lin.

**Conflict of Interest Disclosures:** All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest and none were reported.

**Funding Support:** This research was funded under contract HHSA-290-2012-00015-I-357 EPC4, Task Order 6, from the Agency for Healthcare Research and Quality (AHRQ), US Department of Health and Human Services, under a contract to support the USPSTF.

**Role of the Funder/Sponsor:** Investigators worked with USPSTF members and AHRQ staff to develop the scope, analytic framework, and key questions for this review. AHRQ had no role in study selection, quality assessment, or synthesis. AHRQ staff provided project oversight, reviewed the report to ensure that the analysis met methodological standards, and distributed the draft for peer review. Otherwise, AHRQ had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; and preparation, review, or approval of the manuscript findings. The opinions expressed in this document are those of the authors and do not reflect the official position of AHRQ or the US Department of Health and Human Services.

**Additional Contributions:** We gratefully acknowledge the following individuals for their contributions to this project: Iris Mabry-Hernandez, MD, MPH

(Agency for Healthcare Research and Quality); current and former members of the US Preventive Services Task Force, who contributed to topic deliberations; Wally Krengel, MD (Seattle Children's Hospital), for expert consultation; and Smyth Lai, MLS (Kaiser Permanente Research Affiliates Evidence-based Practice Center), for creating and conducting the literature searches. USPSTF members, expert consultants, and peer reviewers did not receive financial compensation for their contributions.

**Additional Information:** A draft version of this evidence report underwent external peer review from 4 content experts (Marie Beauséjour, PhD, University of Montreal, Sainte-Justine University Hospital Center; M. Timothy Hresko, MD, Harvard Medical School, Boston Children's Hospital; Stefano Negrini, MD, ISICO (Italian Scientific Spine Institute), University of Brescia, Italy; Stuart Weinstein, MD, Pediatric Orthopedic Surgery, University of Iowa) and 2 federal partners: the National Institute of Arthritis and Musculoskeletal and Skin Diseases, and the National Institute of Child Health and Human Development. Comments from reviewers were presented to the USPSTF during its deliberation of the evidence and were considered in preparing the final evidence review.

**Editorial Disclaimer:** This evidence report is presented as a document in support of the accompanying USPSTF Recommendation Statement. It did not undergo additional peer review after submission to *JAMA*.

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