A meta-analysis of the clinical effectiveness of school scoliosis screening

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ABSTRACT

Study Design. A meta-analysis that systematically reviewed the evaluation studies of a scoliosis screening program reported in the literature.

Objective. To evaluate the best current evidence on the clinical effectiveness of school screening for adolescent idiopathic scoliosis.

Summary of Background Data. The use of school scoliosis screening is controversial, and its clinical effectiveness has been diversely reported.

Methods. Data sources included three databases, namely PubMed, Google scholar, CINAHL database, and the references from identified reviews and studies. Studies were included if: 1) they adopted a retrospective cohort design; 2) were screened utilizing either the forward bending test (FBT), angle of trunk rotation, or Moiré topography; 3) reported results of screening tests and radiographic assessments; 4) screened adolescents only; 5) reported the incidence of curves with a minimum Cobb angle of 10° or greater; and 6) reported the number of referrals for radiography. Reviews, comments, case studies, and editorials were excluded.

Results. Thirty-six studies, including thirty-four from the 775 initially identified studies and two from the references, met the selection criteria. The pooled referral rate for radiography was 5.0%, and the pooled positive predictive value (PPV) for detecting curves ≥10°, curves ≥20°, and treatment were 28.0%, 5.6%, and 2.6%, respectively. There was substantial heterogeneity across studies. Meta-regression showed that programs using the FBT alone reported a higher referral rate (odds ratio [OR] = 2.91) and lower PPV for curves ≥10° (OR = 0.49) and curves ≥20° (OR = 0.34) than programs using other tests. Only one small study followed students until skeletal maturity and reported the sensitivity of screening; however, the specificity was not reported. No severe publication bias was noted.

Conclusions. The use of the FBT alone in school scoliosis screening is insufficient. We need large, retrospective cohort studies with sufficient follow-up to properly assess the clinical effectiveness of school scoliosis screening.

Key Words: adolescent idiopathic scoliosis, school screening program, meta-analysis, retrospective cohort studies.

Key Points

- Studies that reported the clinical effectiveness of a school screening program for adolescent idiopathic scoliosis were systematically reviewed. Finally, thirty-six studies were included in a meta-analysis.
- The pooled referral rate for radiography was 5.0%, and the pooled positive predictive values (PPV) for detecting curves ≥10°, curves ≥20°, and treatment were 28.0%, 5.6%, and 2.6%, respectively.
- Programs that used the forward bending test as the only screening tool had a higher referral rate and a lower precision in detecting scoliotic curves.
- Only one small study followed the screened children until their skeletal maturity, and reported the sensitivity of the screening program.

INTRODUCTION

Untreated cases of adolescent idiopathic scoliosis (AIS) may progress, and severe cases are at increased risk for various morbidity problems and mortality.[1] Therefore, most physicians are committed to the early detection of scoliosis and, hence, recommend school scoliosis screening.[2] However, the use of scoliosis screening remains debatable.[3, 4] The main concerns of school scoliosis screening include unnecessary referrals and excessive costs.[3, 5] Several reviews have been conducted, but none of these has been systematic.[2, 3, 6-9]

Different designs have been adopted to evaluate school scoliosis screening. The most recent design is a gender- and age-matched case-control study which concluded that exposure to screening was not significantly different between operated AIS patients and normal subjects.[10] The case-control design generally suffers from confounding factors, and comparing exposure to screening appears to be equivalent to comparing the participation rate rather than the screening accuracy. Indeed, case-control studies are considered as only level III studies.[11] Furthermore, retrospective studies focusing on treated AIS patients found a significantly smaller Cobb angle at detection or a lower operation rate in screened than otherwise detected patients.[12-14] Unfortunately, such analyses would likely over-estimate the screening effectiveness due to 1) lead-time bias when AIS is detected by screening prior to the clinical presentation of spinal deformity that deserves clinical follow-up or treatment and 2) length bias when slowly progressive curves are more likely to be detected by screening than highly progressive curves.[15] There has also been time series studies reporting the number of patients with AIS identified or treated at defined time periods.[16-19] Such a design, however, cannot determine a referral rate for radiography or the positive predictive values that assess the clinical effectiveness. To date, only one randomized controlled trial (RCT) has assessed the accuracy of screening for AIS.[20] However, the study recruited only 15 children, and included no follow-up examination of the children. Indeed, a long follow-up of adolescents until skeletal maturity would be desirable because progression is likely to occur during adolescence. However, this follow-up would mean a period of almost ten years; this procedure may be unethical for children who are not allocated for screening. Additionally, other factors, such as the screeners' experience, use of other screening tests, and the children's participation, would not be considered in an RCT that focuses on efficacy rather than effectiveness. While RCT is a level I design that has the most robust design against various biases, it is not adequate for assessing the clinical effectiveness of school scoliosis screening in a community-based program.

Most other evaluations of school scoliosis screening have been performed in retrospective cohort studies in which a defined cohort of students was followed. Such studies have been performed primarily in a community-based setting, and the design allows different measures of clinical effectiveness to be calculated. Therefore, this level II design is preferable for evaluating school scoliosis screening.[11] However, these studies vary in screening results and conclusions. Therefore, we aimed to systematically review the available retrospective cohort studies to assess the clinical effectiveness of school screening for AIS.

METHODS

Search strategy

Relevant studies were queried using the keywords "screening" and "scoliosis" in the title and abstract fields in PubMed, and then in the title field of Google Scholar under three subject areas: (1) Biology, Life Sciences, and Environmental Science; (2) Medicine, Pharmacology, and Veterinary Science; and (3) Social Sciences, Arts, and Humanities, and finally in the title, abstract, full text, and text word fields of the CINAHL database. Titles and abstracts were screened for potential studies, and full papers were located and read to identify eligible studies. The reference lists from all identified studies and reviews were also examined for additional studies. The search was performed by the first two authors, and the first author, DYTF, has prior experience in systematic review and meta-analysis.

Study selection

Studies were included if they (1) adopted a retrospective cohort design; (2) considered a screening program that utilized either the forward bending test (FBT), angle of trunk rotation (ATR), or Moiré topography; (3) reported results of screening tests and radiographic assessments; (4) screened adolescents only; (5) reported the incidence of curves with a minimum Cobb angle of 10° or greater; and (6) reported the number of referrals for radiography. Reviews, comments, case studies, and editorials were excluded.

Data extraction and meta-analysis

Data were extracted independently by two of the authors using a standardized Excel template. These data included (1) details of the screening, including tests performed, referral criteria, personnel, and period examined; (2) prevalence, calculated for a defined curvature and treatment (brace or surgery) based on the number of screened students; (3) sensitivity, calculated as the proportions of subjects who had a defined curvature and who received treatment detected by screening; (4) specificity, calculated as the proportions of students who did not have a defined curvature and who did not receive treatment correctly identified by screening; and (5) positive predictive value (PPV), calculated as the proportions of students referred for radiography who had a defined curvature and who received treatment. These data, when not reported, were calculated from available data if possible. Figures reported in studies were also verified when reliable data were available. Prevalence, sensitivity, and PPV were calculated for curvatures ≥10° and ≥20°. Note that the negative predictive value (NPV) is often close to 100% in school scoliosis screenings, due to the low prevalence of AIS. Additionally, there was no restriction on the written language of studies; assistance from a professional translation company was sought when there was difficulty understanding the study contents.

The pooled estimates for the prevalence and PPV were obtained by random effects using the exact method based on the binomial distribution.[21] The method is more robust than the commonly used approximation method by DerSimonian and Laird.[21, 22] A heterogeneity test was performed by testing for the significance of the between-study variance. The proportion of total variation in study estimates that is due to heterogeneity, I^2, was calculated as a measure of heterogeneity.[23] Sources of heterogeneity were first explored by a univariable meta-regression on study-specific characteristics, including whether the study examined a routine screening program, whether the study involved screeners specialized in orthopedics, whether the FBT was the only screening test, whether the FBT and ATR were used, and the study's year of publication and size. The study size was classified as large if it was no smaller than the median size and small otherwise. Then, a multivariable meta-regression with a forward selection on the same set of variables was performed. The results were used to guide a subgroup analysis. Publication bias was examined by a funnel plot, which plots the logit of the estimates against their precision, taken as 1/standard error.[24] The meta-analysis was performed with Statistical Analysis System (SAS) Version 9.2.[25]

RESULTS

Identification of studies

A PubMed search performed on January 16, 2008 resulted in 350 citations. Titles and abstracts were screened, and 94 potential studies were identified. After reading the full papers, 27 articles were retained. Google Scholar was searched on September 11, 2008 and yielded 348 citations. After screening titles, abstracts, and full papers where necessary, six eligible studies that were not identified in PubMed were found. The CINAHL database was searched on November 5, 2008, resulting in 77 citations; one study not covered by the above two databases was recognized as eligible. The reference of these articles were read, and two additional studies were found. Finally, 36 retrospective cohort studies (twenty-seven in English, two in Hebrew, two in Simplified Chinese, two in Japanese, one in Danish, one in Spanish, and one in Bulgarian) were reviewed.

The identified studies were published from 17 countries between 1977 and 2005. Details of their screening programs are listed in Table 1. The studies took a median of 3.5 years (range = 0 to 13 years) before they were published after data collection. Ten studies (28%) evaluated a routine screening program, and twenty-four (67%) performed screening as a research or pilot program. The nature of the screening program in the other two studies was not determined due to insufficient information. The three studies that evaluated a routine screening program in Crete, Greece, Rochester, US, and Singapore reported participation rates of 88%, 76%, and 48% respectively. A total of 23 (64%), 5 (14%), and 7 (19%) studies concluded that school scoliosis screening was clinically effective, clinically ineffective, or of uncertain effect, respectively (note that one study had insufficient details).

Screening tests

Twenty-three (64%) studies used the FBT as the only screening test. Eight (22%) studies additionally measured the ATR, and two (6%) further used Moiré topography. One other study used the FBT and Moiré topography, and two others used Moiré topography and low-dose roentgenography. For the eight studies that used the ATR for referring students to radiography, measures from 4° to 15° were used as the minimum criterion. Of the four studies that used Moiré topography, three reported a criterion of

5 mm or 2 lines used; the other study did not report the criterion.

Among the 34 studies that mentioned the background of the screeners, 13 (36%) involved nurses, with one (3%) had a specialization in orthopedics. Other screeners included orthopedists (11), physicians (8), physical therapists (4), pediatricians (2), physical education teachers (1), residents or medical students (3), school medical workers (1), social workers (1), and trained lay volunteers (2). A total of 13 (36%) studies had screeners specialized in orthopedics.

Students screened

The median number of students screened was 5,128 (range = 161 to 968,424). An eligible age range for screening was specified in 30 (83%) studies. Five studies screened students as early as 6 years old, but most studies (eight) started screening students when they were 10 years old. Thirty-three (92%) studies screened both boys and girls, and the remaining three studies screened girls only.

Follow-up information

Sixteen (44%) studies did not provide follow-up information for the screened students, and fifteen (42%) only followed students with detected AIS. Four studies had taken follow-up information for 1 to 3 years on the screened students. Only one study screening 2,242 children had follow-up information from screened students through skeletal maturity.[5] Indeed, this was also the only study that reported the sensitivity as 64.0% (95% confidence interval [CI] = 45.2% to 82.8%) for detecting curves ≥20° and 55.6% (95% CI = 23.1% to 88.0%) for treatment. No studies reported the specificity of school scoliosis screening.

Meta-analysis

The pooled estimates are shown in Table 2. Between-study heterogeneity was significant, with an I^2 greater than 90%. Both univariable and multivariable meta-regression had consistent conclusions regarding the significance of different potential sources. Hence, only the results from multivariable meta-regression are shown in Table 2. More recently published studies demonstrated a 3% lower prevalence of curves ≥10° for each later year. Large studies demonstrated an 84% lower in the odds of treatment prevalence and 70% lower in the odds of PPV for treatment. However, the latter difference was marginally insignificant (p = 0.074), possibly due to the small number of studies (13) reporting treatment information. We also noted that fewer students were referred by large studies than by small studies (OR = 0.49, 95% CI = 0.25 to 0.96, p = 0.037), but this effect became insignificant after accounting for the screening tests. On the other hand, studies that only used the FBT for screening had 191% higher in the odds of referral rate for radiography, and 51% and 66% lower in the odds of PPV for curves ≥10° and ≥20°, respectively. The forest plots and pooled estimates for the corresponding subgroups are shown in Figures 1-3. Study heterogeneity remained significant for the referral rate and PPV for curves ≥10° and ≥20° in all subgroups.

The funnel plots did not indicate severe publication bias. However, the study conducted in Chiba, Japan, may have introduced publication bias in the referral rate and PPV for curves ≥20°. Moreover, another study in Japan was an outlier in terms of its high PPV for curves ≥20° (Figure 3(b)). Indeed, these two studies were the only studies that used low-dose roentgenography for screening; this method is more precise and results in a low referral rate and high PPV for detecting curves. Removal of these studies did not substantially alter the estimates and conclusions, except that the pooled estimate of the PPV for detecting curves ≥20° reduced to 7.6% (95% CI = 2.91% to 12.2%; heterogeneity: $p = 0.087$, $I^2 = 95.8\%$) for studies using the FBT only.

DISCUSSION

This study was the first meta-analysis that estimated the clinical effectiveness of school scoliosis screening. The pooled PPVs for detecting curves ≥10° and ≥20° and treatment were low, which indicates that school scoliosis screening may not have been performed effectively. However, there was considerable heterogeneity across studies with high I^2 and concerns regarding study design. Conclusions made solely based on the pooled estimates may be inadequate.

The meta-regression showed that the use of the FBT alone resulted in a higher referral rate (7.2% vs. 2.6%) and lower PPV for curves ≥10° (23.2% vs. 38.0%) and ≥20° (3.5% vs. 11.0%). However, there was no evidence that the use of the FBT alone influenced the detection of students requiring treatment, which may be due to the fact that only 13 studies (38%) reported treatment details. The use of either the ATR, Moiré topography, low-dose roentgenography, or a combination improved the accuracy of referral, but the evidence was not sufficient to determine if any of these would produce additional benefit. Although the FBT is the most common method for scoliosis screening, it is rather subjective. The evaluation quality may vary with the screeners' experience and qualification. Only two studies were designed to evaluate the use of the FBT for AIS screening, and they reported opposing conclusions.[26-28] Nevertheless, because the FBT is simple and inexpensive, we do not suggest excluding it but recommend the use of additional tests.

Studies published earlier reported a higher prevalence for curves ≥10° than more recently published ones. This difference may be due to the age at which children were screened. Children aged between 10 and 14 years are most likely to develop scoliosis.

In fact, more recent studies tend to screen more children aged outside of this age range. As a result, the prevalence was lowered by the inclusion of these lower risk children in the cohort.

Large studies reported a lower prevalence of treatment (0.07% vs. 0.43% in small studies). Indeed, although the effect became insignificant after considering the use of screening tests, small studies referred subjects more frequently than large studies ($p = 0.037$). This practice may result in higher prevalence estimates among small studies. Moreover, routine screening programs that covered a wider scope of a population were more frequently included in large studies (44%) than in small studies (13%). Nevertheless, there was weak evidence that small studies more accurately identified cases requiring treatment ($p = 0.074$). However, this finding was based on only 13 (38%) studies that reported treatment details. As no similar effect on the PPV for detecting curves ≥10° or ≥20° was observed, this effect remains preliminary.

The I^2 value assesses the between-study variability relative to the within-study variability. The median number of students screened was 5,128, with 30 (83%) studies screened over 1,000 students and 14 (39%) screened more than 10,000. Therefore, within-study variability was small in most studies, and a small difference across studies may result in a high I^2. This is evident from the generally smaller I^2 and larger p-value for testing heterogeneity in small studies. Nevertheless, there may also be other unidentified sources of heterogeneity besides the use of the FBT alone. For example, as AIS is more common in girls than in boys, screening girls only may result in a higher accuracy. However, only three studies screened girls alone, which are likely not representative for assessing the effect of screening girls only.

Only 13 (36%) studies reported treatment outcomes. Two of these studies did not have follow-up data but reported instead the treatments administered by the time AIS patients were confirmed. Two other studies followed patients for 3 years at most. However, AIS is likely to progress during adolescence. Insufficient follow-up may under-estimate the detection rate for treated cases. Absent or insufficient follow-up information for all screened students precludes the reliable determination of the number of AIS patients identified during adolescence, and it is from this number that the sensitivity and specificity are obtained. Clinicians are often interested in predictive values, which are however influenced by the disease prevalence. Therefore, measures of sensitivity and specificity that do not depend on disease prevalence are often preferable. To date, only one study estimated the sensitivity; however, the precision was low, with an error of 32%.[5] Hence, there was a severe lack of large studies that followed students until skeletal maturity.

Despite our efforts to include all studies without written language restrictions, some studies may not have been identified. However, our results based on 36 studies are not likely change, especially because there was no clear indication of publication bias.

In conclusion, there was substantial heterogeneity across studies due to the use of different screening tests and different study sizes. The use of the FBT alone in school scoliosis screening is insufficient. To properly assess the clinical effectiveness of school scoliosis screening, we need large retrospective cohort studies with students followed by skeletal maturity. This assessment could be facilitated by the continuation of school scoliosis screening programs.

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Table 1. Characteristics of school scoliosis screening programs*

	City/Country (Publication year)	Routine screening program?	Screening tests	Screeners	Screening age	Screening period	Follow-up	Total screened (Boys/Girls)	Clinical effectiveness concluded?
1.	Chicago/US[1] (1977)	No	FBT	Physical therapists, orthopedic nurses	NA	NA	None	861 (372/469)	Yes
2.	Oswestry/England[2] (1977)	No	FBT	School nurses	11-14	NA	None	869	Yes
3.	Montreal/Canada[3] (1978)	Yes	FBT	School nurses, physicians	12-14	1974-1976	On cases only (2 years)	26,947 (13,473/13,474)†	Yes
4.	Athens[4] (1979)	No	FBT	Orthopedists	NA	1974	On some cases only (1-2 years)	3,494 (1,874/1,620)	No opinion
5.	Oxford/England[5] (1980)	No	FBT	A senior physiotherapist	13-14	NA	On cases only	1,764	Yes
6.	Wisconsin/US[6] (1981)	Yes	FBT	Trained lay volunteers, physical therapists, nurses	NA	1973-1977	On cases only	8,393 (751/7,642)	Yes
7.	Alabama/US[7] (1983)	No	FBT	Orthopedists	NA	NA	On cases only	561	Yes
8.	Quebec City/ Canada[8] (1985)	No	FBT	Trained nurses	8-15	1977-1978	On cases only	29,195 (14,506/14,689)	No
9.	Changsha and Lian Yuan/China[9] (1985)	No	FBT	Orthopedic surgeons	6-15	1983	On some cases only	8,165 (4,202/3,963)	Yes
10.	Adelaide/Australia[10] (1986)	No	FBT	A nurse	14-16	1982-1983	None	3,660 (1,945/1,715)†	Yes

Table 1. Characteristics of school scoliosis screening programs (cont)*

11. Haifa/Israel[11] (1986)	No	FBT	An orthopedist	10-12	1984-1985	On cases only	2,369 (1,154/1,215)	NA
12. Amman/Jordan[12] (1986)	No	FBT	Doctors	11-16	Feb-May 1982	None	10,287	Yes
13. England[13] (1988)	No	FBT/ATR	NA	11-15	1984	None	5,350	No opinion
14. Chiba/Japan[14] (1988)	Yes	Moiré ≥ 5mm, Low-dose roentgenography	Objectively measured (screeners not mentioned)	10-14	1979-1986	Varied from none till left school	968,424	Yes
15. Beijing/China[15] (1988)	No	FBT/ATR ≥ 3°, Moiré ≥ 5 mm	School medical workers, orthopedists	7-15	1985-1986	On cases only	20,418 (10,283/10,135)	Yes
16. Jeddah/Saudi Arabia[16] (1989)	NA	FBT	Orthopedic surgeons	10-15	NA	On cases only	4,907 (3,649/1,258)	No
17. Riyadh/Saudi Arabia[17] (1994)	No	FBT	Nurses, a social worker	10-17	1990-1991	None	4,018 (girls only)	Yes
18. Herning/Denmark[18] (1994)	No	FBT, Moiré	Specialist in orthopedic surgery	10-17	1981	On cases only	989 (girls only)	No
19. Dublin/US[19] (1995)	No	FBT and Premenarchal ATR (thoracic) ≥ 8° or ATR (loin) ≥ 10° Postmenarchal ATR (thoracic) ≥ 10° or ATR (loin) ≥ 15°	A physician, a physical education teacher, a school nurse	10-14	1986-1987	3 years	8,686 (girls only)	No

Table 1. Characteristics of school scoliosis screening programs (cont)*

20.	Shanxi/China[20] (1995)	No	FBT/ATR ≥ 4°	Physicians, nurses, medical students	7-18	1992-1993	None	24,130 (11,583/12,547)	Yes
21.	Galilee/Israel[21] (1996)	NA	FBT	Trained person, orthopedist	9-13	NA	None	2,940 (1,733/1,207)	No
22.	Central Netherlands[22] (1996)	Yes	FBT, rib hump height, ATR ≥ 5°, Moiré ≥ 2 lines	Trained physicians, an orthopedist	10, 12, 14	1983-1984	3 years	30,611	Yes
23.	Leeds/England[23] (1996)	No	FBT/ATR ≥ 5°	Trained research nurses	6-14	NA	None	15,799 (8,186/7,613)	No opinion
24.	Sofia/Bulgaria[24] (1996)	No	FBT	Orthopedic surgeons	11-15	1995-1996	None	4,800	Yes
25.	Beijing/China[25] (1996)	No	FBT/ATR ≥ 5°	Physicians	8-14	1986	None	21,759	Yes
26.	Ankara/Turkey[26] (1997)	No	FBT	Residents in physical medicine & rehabilitation	6-13	1994-1995	None	4,682 (2,466/2,216)	Yes
27.	Crete/Greece[27] (1997)	Yes	FBT	General practitioners, physicians, nurses	6-12	1990-1992	On cases only (6-12 months)	21,220 (10,942/10,278)	No opinion
28.	Northwestern and Central Greece[28] (1997)	No	FBT	Orthopedic residents, medical students, senior orthopedic surgeons	9-14	1993-1994	None	82,901 (41,939/40,962)	Yes
29.	Kagawa/Japan[29] (1999)	No	FBT	Physical therapist	NA	1997	None	468	Yes

Table 1. Characteristics of school scoliosis screening programs (cont)*

30. Japan[30] (1999)	Yes	Moiré ≥ 5mm, Low-dose roentgenography	Objectively measured (screeners not mentioned)	10-13	1997	None	56,788 (28362/28426)	Yes
31. Spain[31] (1999)	No	FBT	Pediatrician	10-15	NA	On cases only	161 (92/69)	No
32. Rochester/US[32] (1999)	Yes	FBT/ATR ≥ 7° (yearly in Grade 5-9)	Public health nurses supervised by an orthopedic surgeon	8-19	1984-1989	Up to age 19 years	2,242	No opinion
33. Thriasio/Greece[33] (2002)	No	FBT/ATR ≥ 7°	NA	5.5-17.5	1977-1999	On cases only	3,039 (1,506/1,533)	Yes
34. Israel[34] (2002)	Yes	FBT	Trained pediatrician	12-18	5 year	On cases only	2,380 (1,142/1,238)	Yes
35. Columbia/US[35] (2002)	Yes	FBT	School nurses	NA	1989-1996	Varied from none to 1 year	52,300	No opinion
36. Singapore[36] (2005)	Yes	FBT/ATR ≥ 5°	Experienced registered nurses, medical officers	6-14	1997	None	72,699 (35,558/37,141)	Yes

*ATR = Angle of trunk rotation; FBT = Forward bending test; NA = Details not available

†Estimated figures

Table 2. Pooled estimates and multivariable meta-regression

Outcome	No. of studies	Pooled estimate (95% CI)	Heterogeneity p-value	Heterogeneity I^2†	Multivariable meta-regression Source of heterogeneity‡	OR (95% CI)§	p-value
Prevalence							
Cobb angle ≥ 10°	34	1.3% (1.0%, 1.7%)	0.001	98.9%	Year of publication	0.97 (0.94, 1.00)	0.037
Cobb angle ≥ 20°	28	0.2% (0.2%, 0.3%)	0.006	97.6%	-	-	-
Treatment	13	0.2% (0.0%, 0.3%)	0.043	96.1%	Large vs. small studies	0.16 (0.06, 0.47)	0.003
Referral rate	36	5.0% (3.3%, 6.7%)	<0.001	99.9%	Used FBT only	2.91 (1.53, 5.54)	0.002
Positive predictive value							
Cobb angle ≥ 10°	34	28.0% (21.3%, 34.7%)	0.001	98.9%	Used FBT only	0.49 (0.25, 0.96)	0.037
Cobb angle ≥ 20°	28	5.6% (2.9%, 8.3%)	0.002	98.9%	Used FBT only	0.34 (0.15, 0.79)	0.013
Treatment	13	2.6% (0.9%, 4.2%)	0.039	94.5%	-	-	-

† Proportion of total variation in study estimates that is due to heterogeneity.

‡ A study was considered large when the number of students screened was at least the median. FBT = Forward bending test.

§ OR = Odds ratio; those ORs for the positive predictive value were adjusted for the corresponding prevalence.

Figure Legends

Figure 1. Pooled estimate of prevalence of adolescent idiopathic scoliosis

(a) with a Cobb angle of at least 10°

(b) with a Cobb angle of at least 20°

(c) with treatment

Figure 2. Pooled estimate of referral rate for radiography

Figure 3. Pooled estimates of positive predictive values

(a) for a Cobb angle of at least 10°

(b) for a Cobb angle of at least 20°

(c) for treatment

Figure 1a

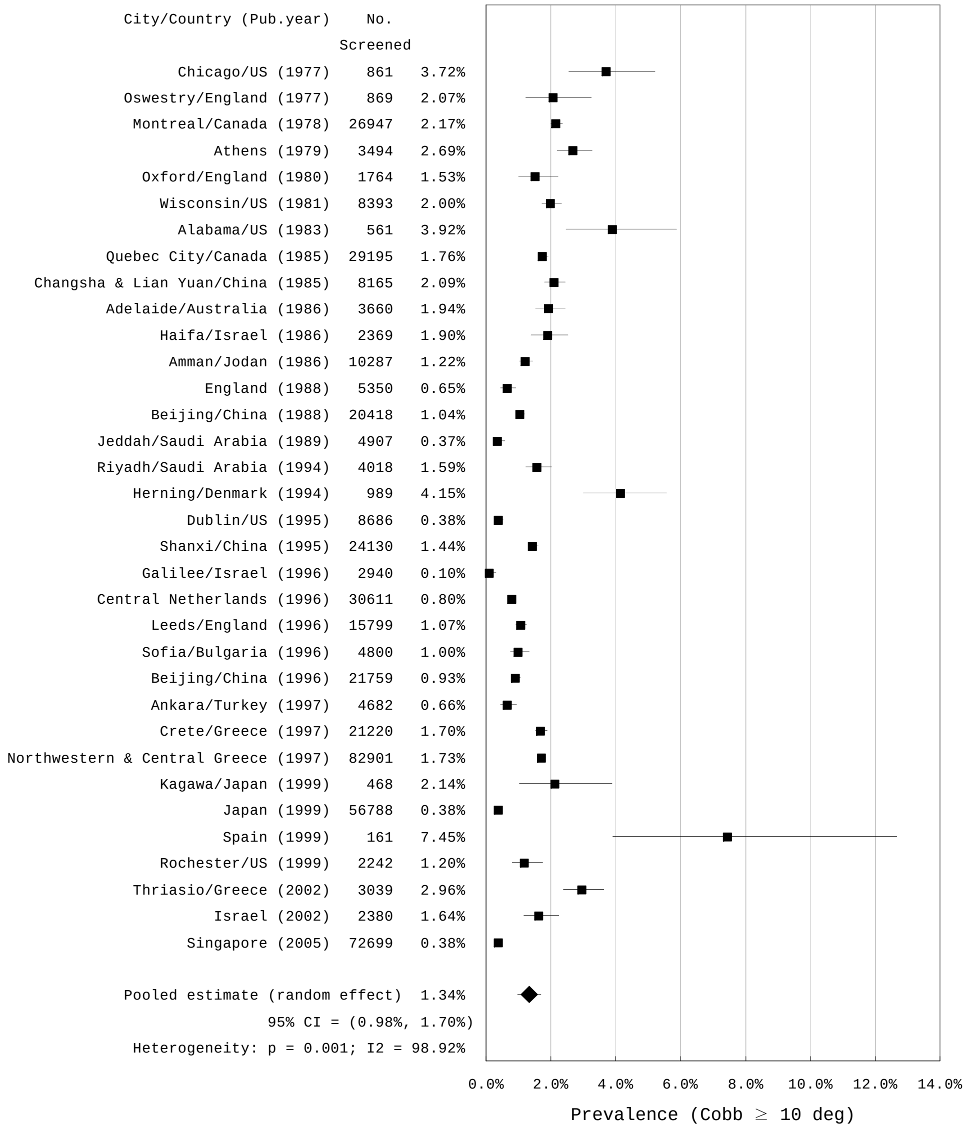

City/Country (Pub.year) No. Screened
Chicago/US (1977) 861 3.72%
Oswestry/England (1977) 869 2.07%
Montreal/Canada (1978) 26947 2.17%
Athens (1979) 3494 2.69%
Oxford/England (1980) 1764 1.53%
Wisconsin/US (1981) 8393 2.00%
Alabama/US (1983) 561 3.92%
Quebec City/Canada (1985) 29195 1.76%
Changsha & Lian Yuan/China (1985) 8165 2.09%
Adelaide/Australia (1986) 3660 1.94%
Haifa/Israel (1986) 2369 1.90%
Amman/Jodan (1986) 10287 1.22%
England (1988) 5350 0.65%
Beijing/China (1988) 20418 1.04%
Jeddah/Saudi Arabia (1989) 4907 0.37%
Riyadh/Saudi Arabia (1994) 4018 1.59%
Herning/Denmark (1994) 989 4.15%
Dublin/US (1995) 8686 0.38%
Shanxi/China (1995) 24130 1.44%
Galilee/Israel (1996) 2940 0.10%
Central Netherlands (1996) 30611 0.80%
Leeds/England (1996) 15799 1.07%
Sofia/Bulgaria (1996) 4800 1.00%
Beijing/China (1996) 21759 0.93%
Ankara/Turkey (1997) 4682 0.66%
Crete/Greece (1997) 21220 1.70%
Northwestern & Central Greece (1997) 82901 1.73%
Kagawa/Japan (1999) 468 2.14%
Japan (1999) 56788 0.38%
Spain (1999) 161 7.45%
Rochester/US (1999) 2242 1.20%
Thriasio/Greece (2002) 3039 2.96%
Israel (2002) 2380 1.64%
Singapore (2005) 72699 0.38%
Pooled estimate (random effect) 1.34%
95% CI = (0.98%, 1.70%)
Heterogeneity: p = 0.001; I2 = 98.92%
0.0% 2.0% 4.0% 6.0% 8.0% 10.0% 12.0% 14.0%
Prevalence (Cobb ≥ 10 deg)

Figure 1b

City/Country (Pub.year)	No. Screened	
Montreal/Canada (1978)	26947	0.29%
Athens (1979)	3494	0.43%
Wisconsin/US (1981)	8393	0.49%
Quebec City/Canada (1985)	29195	0.34%
Changsha & Lian Yuan/China (1985)	8165	0.12%
Adelaide/Australia (1986)	3660	0.87%
Haifa/Israel (1986)	2369	0.30%
England (1988)	5350	0.24%
Chiba/Japan (1988)	968424	0.24%
Beijing/China (1988)	20418	0.29%
Jeddah/Saudi Arabia (1989)	4907	0.02%
Riyadh/Saudi Arabia (1994)	4018	0.37%
Herning/Denmark (1994)	989	0.91%
Shanxi/China (1995)	24130	0.27%
Galilee/Israel (1996)	2940	0.03%
Central Netherlands (1996)	30611	0.19%
Leeds/England (1996)	15799	0.07%
Sofia/Bulgaria (1996)	4800	0.29%
Ankara/Turkey (1997)	4682	0.06%
Crete/Greece (1997)	21220	0.06%
Northwestern & Central Greece (1997)	82901	0.22%
Japan (1999)	56788	0.28%
Rochester/US (1999)	2242	0.71%
Thriasio/Greece (2002)	3039	0.53%
Israel (2002)	2380	0.50%
Columbia/US (2002)	52300	0.06%
Singapore (2005)	72699	0.15%

Pooled estimate (random effect) 0.22%

95% CI = (0.15%, 0.30%)

Heterogeneity: p = 0.006; I2 = 97.58%

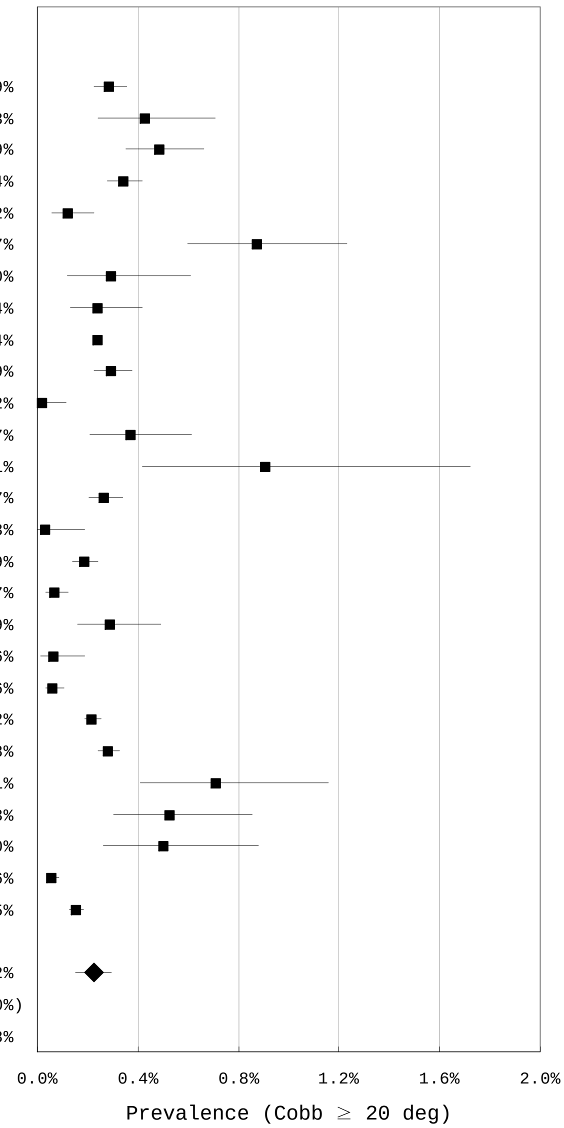


Figure 1c

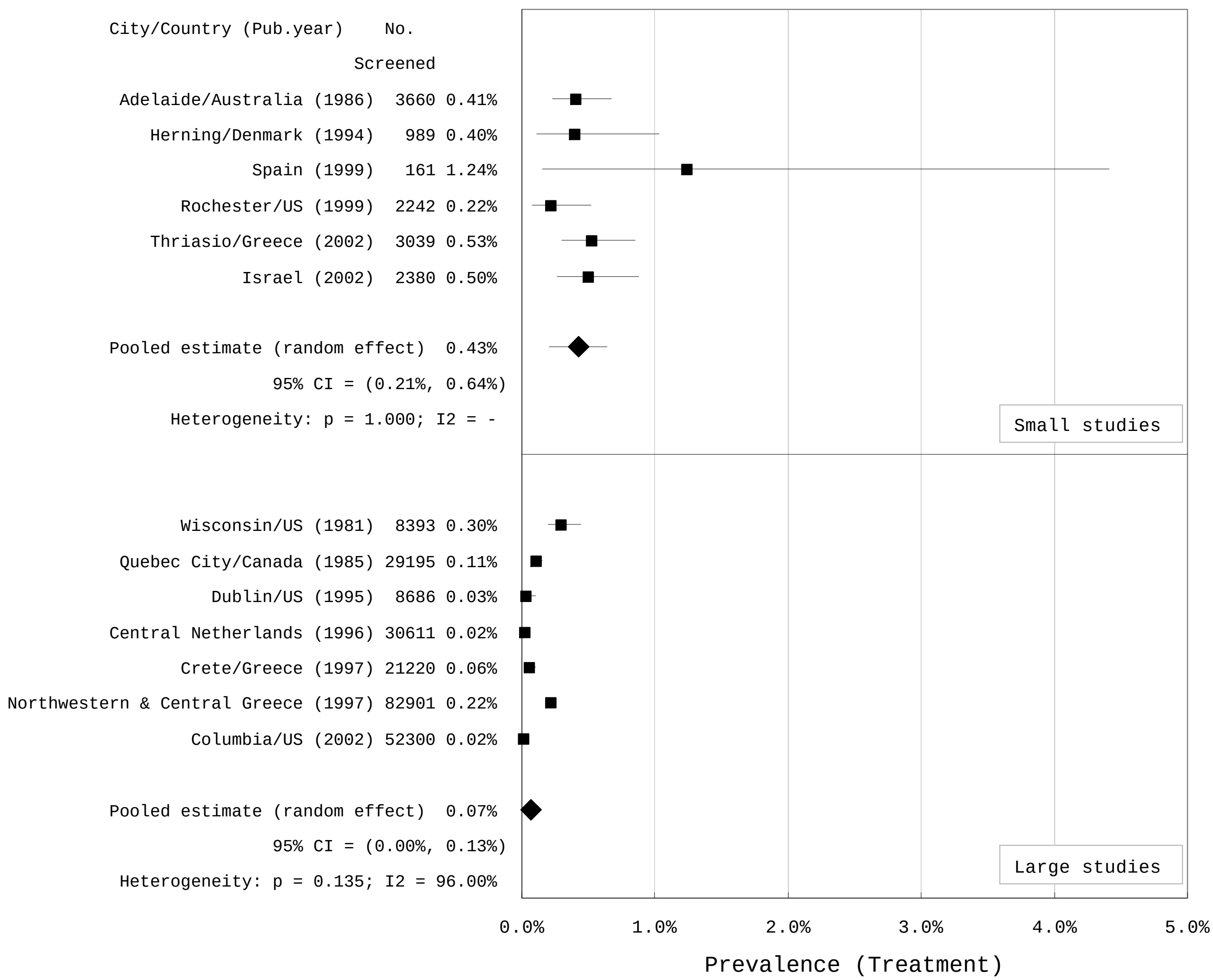

City/Country (Pub.year) No. Screened
Adelaide/Australia (1986) 3660 0.41%
Herning/Denmark (1994) 989 0.40%
Spain (1999) 161 1.24%
Rochester/US (1999) 2242 0.22%
Thriasio/Greece (2002) 3039 0.53%
Israel (2002) 2380 0.50%
Pooled estimate (random effect) 0.43%
95% CI = (0.21%, 0.64%)
Heterogeneity: p = 1.000; I2 = -
Small studies
Wisconsin/US (1981) 8393 0.30%
Quebec City/Canada (1985) 29195 0.11%
Dublin/US (1995) 8686 0.03%
Central Netherlands (1996) 30611 0.02%
Crete/Greece (1997) 21220 0.06%
Northwestern & Central Greece (1997) 82901 0.22%
Columbia/US (2002) 52300 0.02%
Pooled estimate (random effect) 0.07%
95% CI = (0.00%, 0.13%)
Heterogeneity: p = 0.135; I2 = 96.00%
Large studies
0.0%
1.0%
2.0%
3.0%
4.0%
5.0%
Prevalence (Treatment)

Figure 2

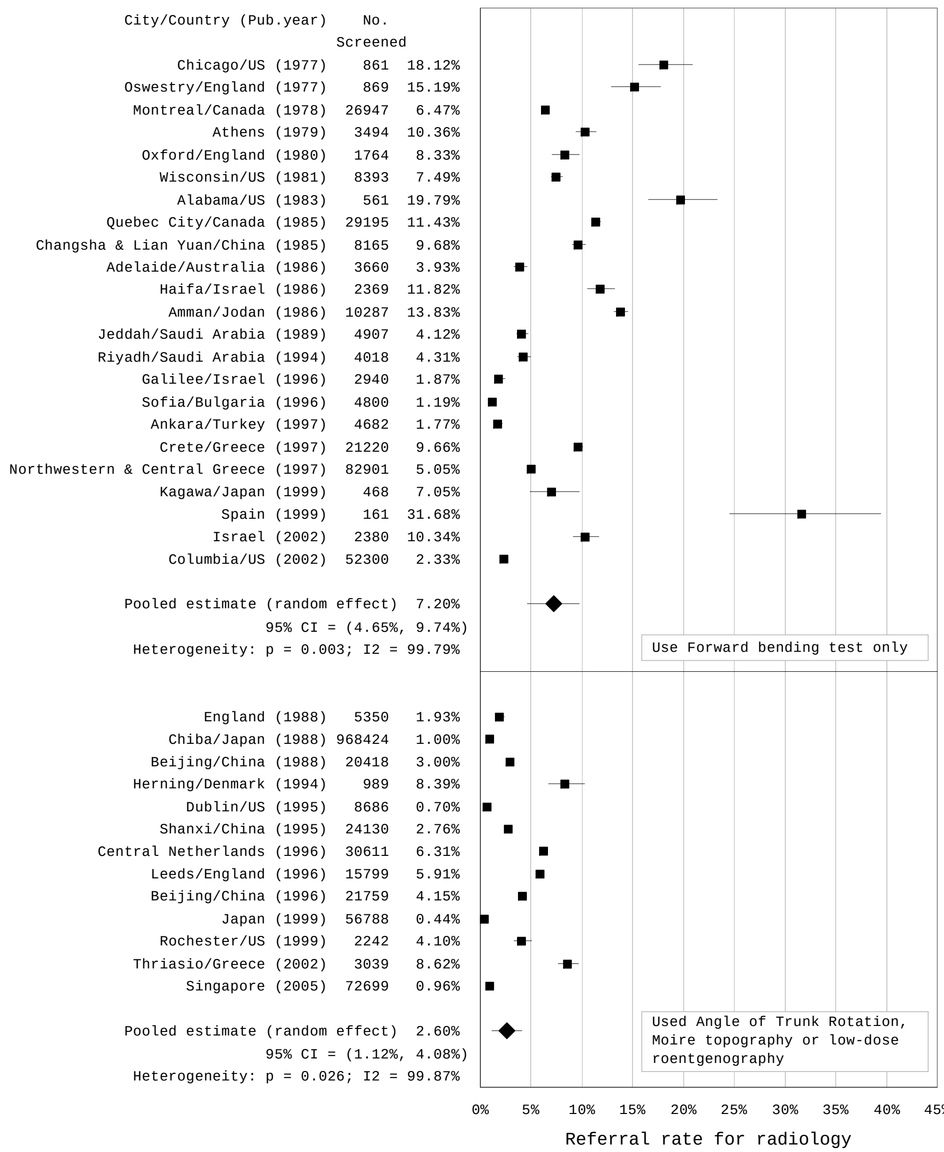

City/Country (Pub.year) No. Screened
Chicago/US (1977) 861 18.12%
Oswestry/England (1977) 869 15.19%
Montreal/Canada (1978) 26947 6.47%
Athens (1979) 3494 10.36%
Oxford/England (1980) 1764 8.33%
Wisconsin/US (1981) 8393 7.49%
Alabama/US (1983) 561 19.79%
Quebec City/Canada (1985) 29195 11.43%
Changsha & Lian Yuan/China (1985) 8165 9.68%
Adelaide/Australia (1986) 3660 3.93%
Haifa/Israel (1986) 2369 11.82%
Amman/Jodan (1986) 10287 13.83%
Jeddah/Saudi Arabia (1989) 4907 4.12%
Riyadh/Saudi Arabia (1994) 4018 4.31%
Galilee/Israel (1996) 2940 1.87%
Sofia/Bulgaria (1996) 4800 1.19%
Ankara/Turkey (1997) 4682 1.77%
Crete/Greece (1997) 21220 9.66%
Northwestern & Central Greece (1997) 82901 5.05%
Kagawa/Japan (1999) 468 7.05%
Spain (1999) 161 31.68%
Israel (2002) 2380 10.34%
Columbia/US (2002) 52300 2.33%
Pooled estimate (random effect) 7.20%
95% CI = (4.65%, 9.74%)
Heterogeneity: p = 0.003; I2 = 99.79%
Use Forward bending test only
England (1988) 5350 1.93%
Chiba/Japan (1988) 968424 1.00%
Beijing/China (1988) 20418 3.00%
Herning/Denmark (1994) 989 8.39%
Dublin/US (1995) 8686 0.70%
Shanxi/China (1995) 24130 2.76%
Central Netherlands (1996) 30611 6.31%
Leeds/England (1996) 15799 5.91%
Beijing/China (1996) 21759 4.15%
Japan (1999) 56788 0.44%
Rochester/US (1999) 2242 4.10%
Thriasio/Greece (2002) 3039 8.62%
Singapore (2005) 72699 0.96%
Pooled estimate (random effect) 2.60%
95% CI = (1.12%, 4.08%)
Heterogeneity: p = 0.026; I2 = 99.87%
Used Angle of Trunk Rotation, Moire topography or low-dose roentgenography
0% 5% 10% 15% 20% 25% 30% 35% 40% 45%
Referral rate for radiology

Figure 3a

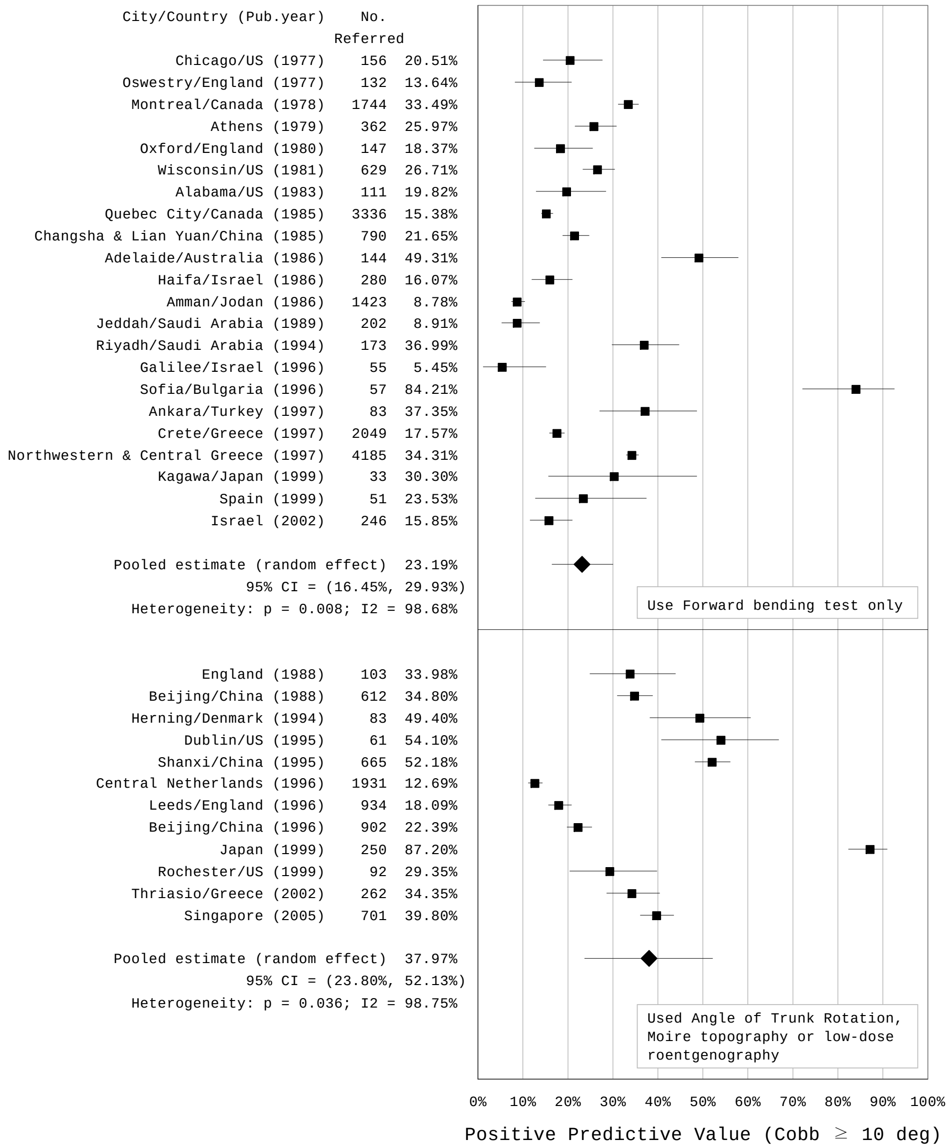

City/Country (Pub.year) No. Referred
Chicago/US (1977) 156 20.51%
Oswestry/England (1977) 132 13.64%
Montreal/Canada (1978) 1744 33.49%
Athens (1979) 362 25.97%
Oxford/England (1980) 147 18.37%
Wisconsin/US (1981) 629 26.71%
Alabama/US (1983) 111 19.82%
Quebec City/Canada (1985) 3336 15.38%
Changsha & Lian Yuan/China (1985) 790 21.65%
Adelaide/Australia (1986) 144 49.31%
Haifa/Israel (1986) 280 16.07%
Amman/Jodan (1986) 1423 8.78%
Jeddah/Saudi Arabia (1989) 202 8.91%
Riyadh/Saudi Arabia (1994) 173 36.99%
Galilee/Israel (1996) 55 5.45%
Sofia/Bulgaria (1996) 57 84.21%
Ankara/Turkey (1997) 83 37.35%
Crete/Greece (1997) 2049 17.57%
Northwestern & Central Greece (1997) 4185 34.31%
Kagawa/Japan (1999) 33 30.30%
Spain (1999) 51 23.53%
Israel (2002) 246 15.85%
Pooled estimate (random effect) 23.19%
95% CI = (16.45%, 29.93%)
Heterogeneity: p = 0.008; I2 = 98.68%
Use Forward bending test only
England (1988) 103 33.98%
Beijing/China (1988) 612 34.80%
Herning/Denmark (1994) 83 49.40%
Dublin/US (1995) 61 54.10%
Shanxi/China (1995) 665 52.18%
Central Netherlands (1996) 1931 12.69%
Leeds/England (1996) 934 18.09%
Beijing/China (1996) 902 22.39%
Japan (1999) 250 87.20%
Rochester/US (1999) 92 29.35%
Thriasio/Greece (2002) 262 34.35%
Singapore (2005) 701 39.80%
Pooled estimate (random effect) 37.97%
95% CI = (23.80%, 52.13%)
Heterogeneity: p = 0.036; I2 = 98.75%
Used Angle of Trunk Rotation, Moire topography or low-dose roentgenography
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Positive Predictive Value (Cobb ≥ 10 deg)

Figure 3b

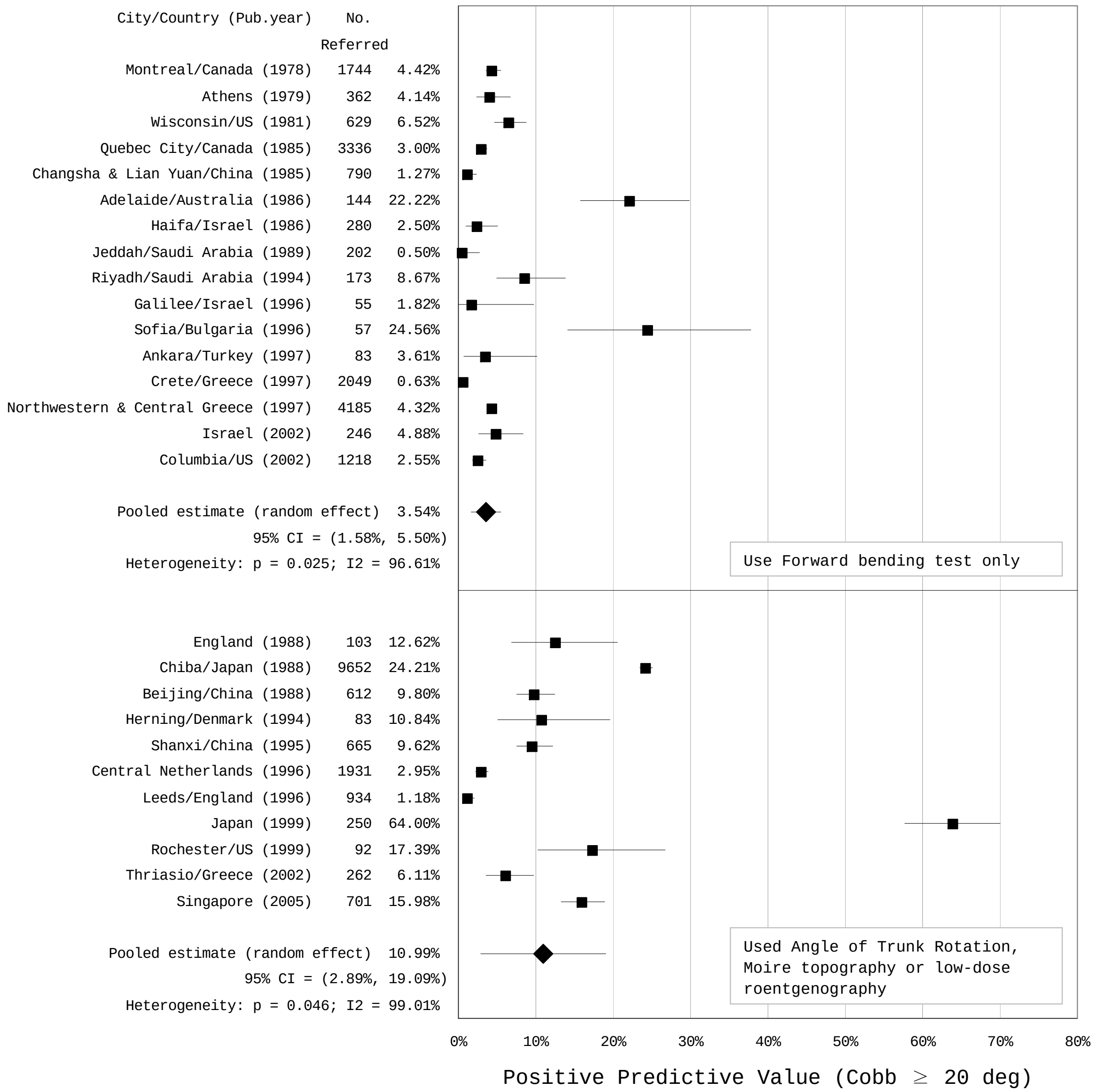
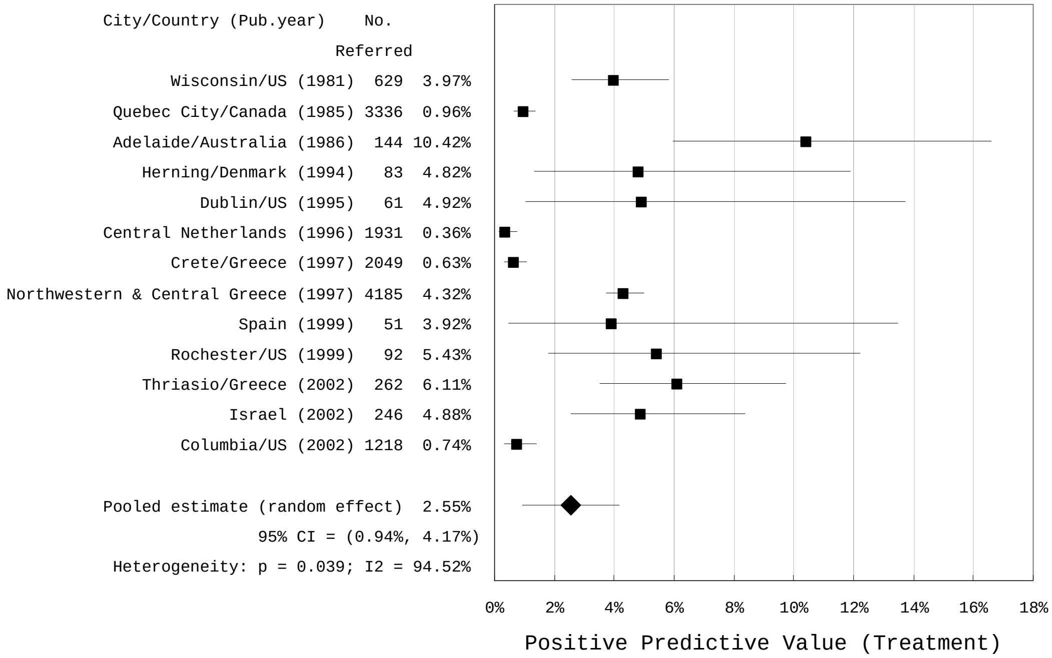

City/Country (Pub.year) No. Referred
Montreal/Canada (1978) 1744 4.42%
Athens (1979) 362 4.14%
Wisconsin/US (1981) 629 6.52%
Quebec City/Canada (1985) 3336 3.00%
Changsha & Lian Yuan/China (1985) 790 1.27%
Adelaide/Australia (1986) 144 22.22%
Haifa/Israel (1986) 280 2.50%
Jeddah/Saudi Arabia (1989) 202 0.50%
Riyadh/Saudi Arabia (1994) 173 8.67%
Galilee/Israel (1996) 55 1.82%
Sofia/Bulgaria (1996) 57 24.56%
Ankara/Turkey (1997) 83 3.61%
Crete/Greece (1997) 2049 0.63%
Northwestern & Central Greece (1997) 4185 4.32%
Israel (2002) 246 4.88%
Columbia/US (2002) 1218 2.55%
Pooled estimate (random effect) 3.54%
95% CI = (1.58%, 5.50%)
Heterogeneity: p = 0.025; I2 = 96.61%
Use Forward bending test only
England (1988) 103 12.62%
Chiba/Japan (1988) 9652 24.21%
Beijing/China (1988) 612 9.80%
Herning/Denmark (1994) 83 10.84%
Shanxi/China (1995) 665 9.62%
Central Netherlands (1996) 1931 2.95%
Leeds/England (1996) 934 1.18%
Japan (1999) 250 64.00%
Rochester/US (1999) 92 17.39%
Thriasio/Greece (2002) 262 6.11%
Singapore (2005) 701 15.98%
Pooled estimate (random effect) 10.99%
95% CI = (2.89%, 19.09%)
Heterogeneity: p = 0.046; I2 = 99.01%
Used Angle of Trunk Rotation, Moire topography or low-dose roentgenography
0% 10% 20% 30% 40% 50% 60% 70% 80%
Positive Predictive Value (Cobb ≥ 20 deg)

Figure 3c


City/Country (Pub.year) No. Referred
Wisconsin/US (1981) 629 3.97%
Quebec City/Canada (1985) 3336 0.96%
Adelaide/Australia (1986) 144 10.42%
Herning/Denmark (1994) 83 4.82%
Dublin/US (1995) 61 4.92%
Central Netherlands (1996) 1931 0.36%
Crete/Greece (1997) 2049 0.63%
Northwestern & Central Greece (1997) 4185 4.32%
Spain (1999) 51 3.92%
Rochester/US (1999) 92 5.43%
Thriasio/Greece (2002) 262 6.11%
Israel (2002) 246 4.88%
Columbia/US (2002) 1218 0.74%
Pooled estimate (random effect) 2.55%
95% CI = (0.94%, 4.17%)
Heterogeneity: p = 0.039; I2 = 94.52%
0% 2% 4% 6% 8% 10% 12% 14% 16% 18%
Positive Predictive Value (Treatment)