SPINE Volume 24, Number 22, pp 2318–2324

Ten-Year Follow-Up Evaluation of a School Screening Program for Scoliosis

Is the Forward-Bending Test an Accurate Diagnostic Criterion for the Screening of Scoliosis?

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Study Design. A 10-year follow-up evaluation of the effectiveness of school screening for scoliosis performed in a closed island population.

Objectives. To evaluate the diagnostic accuracy of methods used for screening scoliosis and to re-examine the long-term effectiveness of the school scoliosis screening program.

Summary of Background Data. The diagnostic accuracy of the forward-bending test and the long-term efficacy of the screening programs have not been clearly established.

Methods. In 1987, 2700 pupils aged 8 to 16 years from the island of Samos were screened for scoliosis. The Adams forward-bending test, Moire topography, the scoliometer, and the humpometer were used. Radiologic evaluation of the spine was available for each pupil and the number of false-negative and false-positive results of the screening methods was calculated. Subsequently, sensitivity, specificity, and positive and negative predictive values were estimated for each screening technique. Pupils found positive for spinal deformity were then followed up regularly at yearly intervals. In 1997, all positive subjects attended a 10-year clinical and radiologic follow-up, and the remaining subjects were re-evaluated by a postal questionnaire and were clinically examined if necessary.

Results. Spinal deformity was found in 153 (5.66%) pupils. Scoliosis (defined as a spinal curvature ≥10°) was found in 32 pupils, for a prevalence of 1.18%. For scoliosis, the Adams forward-bending test showed a number of false-negative results (in five cases), for a sensitivity of 84.37% and specificity of 93.44%. The sensitivities of Moire topography, the humpometer, and the scoliometer were 100%, 93.75%, and 90.62%, respectively, and specificity was 85.38%, 78.11%, and 79.76% respectively. The negative predictive value of the forward-bending test was inferior to those of the other methods. During this scoliosis screening program, if cutoff limits for referral had been used, such as the asymmetry of two Moire fringes, a humpogram deformity of (D+H) = 10 mm, and 8° of scoliometer angle, it would have been possible to reduce radiologic examination by 89.4%. Three (0.11%) pupils aged between 12 and 14 years with scoliotic deformities greater than 20° underwent satisfactory nonoperative treatment with Boston braces. One pupil with a 40° thoracic curvature, underwent satisfactory surgical treatment because of progression 1 year later. Of the 121 spinal deformities with an initial Cobb angle less than 10°, 44 (35.8%), and of the 29 scoliotic deformities with an initial Cobb angle between 10° and 20°, 14 (48.3%) progressed (a Cobb angle difference of at least 5° in more than one examination). Observation and physiotherapy were the only treatments applied to all except one of the pupils in these groups.

Conclusions. The Adams forward-bending test cannot be considered a safe diagnostic criterion for the early detection of scoliosis (especially when it is used as the only screening tool) because it results in an unacceptable number of false-negative findings. For the early detection of scoliosis, a combination of back-shape analysis methods can be safely used with the introduction of cutoff limits for referral being a useful procedure. The incidence of significant scoliosis is low, and its natural history seems to be independent of early detection. The widespread use of school scoliosis screening with the use of the forward-bending test must be questioned. [Key words: Adams forward-bending test, humpogram, Moire topography, scoliometer, scoliosis, scoliosis screening] **Spine 1999;24:2318–2324**

The methodology and effectiveness of several screening tests for scoliosis have been the subject of many studies. Most of these initial tests were based on clinical examination and the Adams forward-bending test (FBT).[5,27] However, clinical examination was shown to have some drawbacks when used as the only diagnostic tool for the early detection of scoliosis[5,16] and radiologic examination for the same use is condemned, because it is considered not only expensive but also harmful to the health of the growing child.[22]

Thus, several methods were developed in an attempt to predict scoliotic deformities from altered back shape and trunk deformities. Back contour and shape were originally recorded by humpograms as described by Thulbourne and Gillespie[30] and Burwell.[8] The scoliometer was used—a goniometer specifically designed for the assessment of the angle of trunk rotation, which represents one of the components of clinical scoliotic deformity.[6] Efforts have been made to develop mechanical screening methods that do not rely on subjective appraisal. Moire topography is a photostereometric method that measures asymmetry of the body surface

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Acknowledgment date: September 9, 1998.
First revision date: January 26, 1999.
Acceptance date: April 26, 1999.
Device status category: 6.

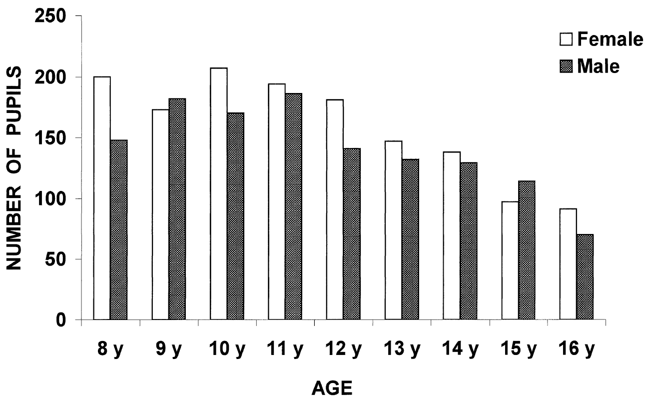

Figure 1. The age distribution of the school population screened for scoliosis.

resulting mainly from deformity of the ribs and muscles.[10] This method has become an accepted method in the diagnosis and documentation of scoliosis, because it is a noninvasive technique that sets down in three dimensions the shape and contour of the dorsal surface of the human body.[26] Later, the integrated shape-imaging system (ISIS) was proposed by Turner–Smith et al,[32] whereas Stokes and Moreland[29] used raster stereography to study back shape abnormalities. Several other high-technology methods have been used for the same purposes, including an ultrasound real-time linear array scanner,[19] optoelectronic circumferential scanning,[11] and digitization of the spinous processes.[36] Despite all these efforts to develop new methods or devices for screening purposes, not one of them is currently in frequent use. The traditional methods such as the Adams forward-bending test, the assessment of the angle of trunk rotation by scoliometer, Moire topography, and the measurement of rib hump form the basis of most of the worldwide reported screening tests.

Surprisingly, there are few studies in which investigators have compared the efficacy of the various early scoliosis detection methods, and several questions concerning sensitivity, specificity, and negative prognostic value of the above-mentioned methods still exist.[3,34]

The purpose of this study was to evaluate the diagnostic validity and safety of the methods used for screening scoliosis including FBT and back-shape analyses; to compare the sensitivity, specificity, and negative and positive prognostic values of the described methods; and to

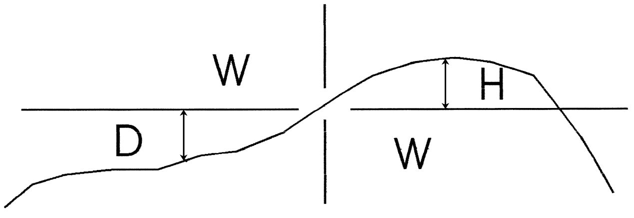

Figure 2. Humpogram (line drawing). The parameter for back deformity (H+D) is shown. H=Hump (mm); D=Depression (mm); (H+D)=Deformation (mm).

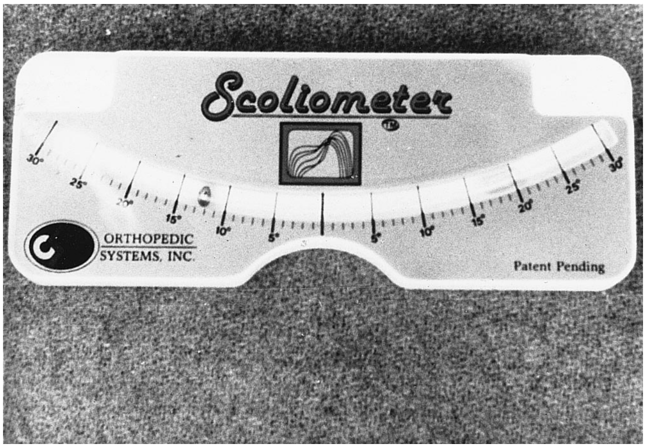

Figure 3. The scoliometer. Reprinted, with permission, from Bunnel W. An objective criterion for scoliosis screening. J Bone Joint Surg [Am] 1984;66:1381–7.

present the long-term efficacy of a school screening test in detecting and treating scoliosis in the closed population of an island.

■ Materials and Methods

In 1987, during a massive school screening test on the island of Samos, Greece, all 2700 pupils more than 8 years of age in the local schools were examined. These pupils were representative of the island's social structure (251 pupils came from Navy families, 1069 from rural and laborers' families, 529 from public officers' families, 810 from self-employed families, and 41 from scientists' families). The age distribution for male and female pupils is shown in Figure 1.

For the purposes of this screening test, medical, nursing, and paramedical staff were divided into three groups. Each group included two senior orthopedic surgeons specializing in spinal surgery who examined 900 pupils and recorded data according to a specific protocol of clinical and laboratory tests. Pupils were classified as positive or negative in all methods used for the detection of scoliosis by two independent evaluations, and the consequent recordings of the two orthopedic examiners of

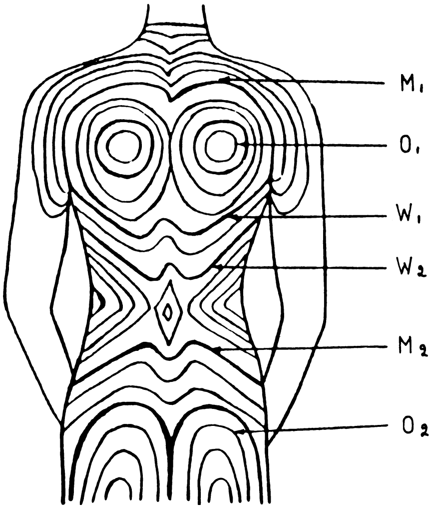

Figure 4. Moire topography. Line drawing of the location of the asymmetry of the fringes at all levels of the spine.

each examining group. In the case of disagreement, a further examination was performed in the presence of a third examiner, and a final recording was made.

All pupils were clinically examined both by inspection (trunk asymmetry) and by the Adams FBT.[1] Each pupil found positive on clinical examination was isolated, and a clinical estimation of the level (T, TL, L) and side (L or R) of the curvature was recorded. Humpograms (Figure 2) of the backs of all pupils were first taken at three spinal levels (thoracic [T], thoracolumbar [TL], and lumbar [L]) using the humpometer.[30] The parameter for back deformity (H+D) was recorded and considered to be positive when its value exceeded 5 mm (>5 mm).[25] Any H+D value greater than or equal to 5 mm was recorded as the value for hump A, whereas values with a range between 0–5 mm were recorded as hump B values. All pupils were then examined using the scoliometer (inclinometer; Figure 3), and the angle of thoracic inclination was estimated as defined by The Scoliosis Research Society.[6] This angle (angle of trunk rotation) is determined as the angle between the horizontal and a plane across the posterior aspect of the trunk at the point or points of maximum deformity, and in this study, all recorded angle values greater than 0° were considered to show a positive result. Measurements with this device were conducted at all levels of the spine, and the maximum angle of trunk rotation was recorded and used for statistical analysis.

All pupils were also examined using Moire topography. The topographs were initially classified by optical assessment[20] and then photographed. The photos were studied according to Willner's method.[35] Two independent examiners assessed the asymmetry of Moire fringes in the regions, as depicted in Figure 4.

Finally, all pupils found positive on either clinical examination and FBT or in any of the back-shape analysis methods were subjected to conventional anteroposterior standing radiologic examination. Because this scoliosis school screening test was followed by a screening test for lung diseases, low-dose long chest radiographs were also obtained[24,25] and were available for the remainder of the pupils. Although the low-dose long chest radiographs clearly showed all vertebral bodies from C7 to L1 or L2, there was the possibility of missing a small number of lumbar curvatures. In any pupil with suspected spinal curvature showed by the low-dose long chest radiograph, a further conventional radiologic examination and subsequent measurements were performed.

For all pupils in whom spinal curvatures were found, the level (T, TL, and L) of the curvature, the Cobb angle, and the rotation of the apex vertebra were recorded.[23] All spinal curvatures with a Cobb angle equal or greater than 5° were recorded, and all curvatures with a Cobb angle equal to or greater than 10° were considered to be cases of scoliosis. For both types of radiologic examination, parents provided written consent. The existence of such radiologic data allowed safe estimation of the sensitivity, specificity, and negative and positive predictive values of all the methods used for scoliosis detection.

In all pupils in whom spinal deformity was diagnosed, a decision about treatment or observation was made as necessary. They were then all observed regularly at the outpatient orthopedic clinics of the local General County Hospital. Finally, a 10-year (average, 10 years) clinical and radiologic follow-up evaluation of these subjects was organized in 1997. At the same time (1997) the remaining subjects were re-evaluated by a postal questionnaire and were clinically examined if necessary.

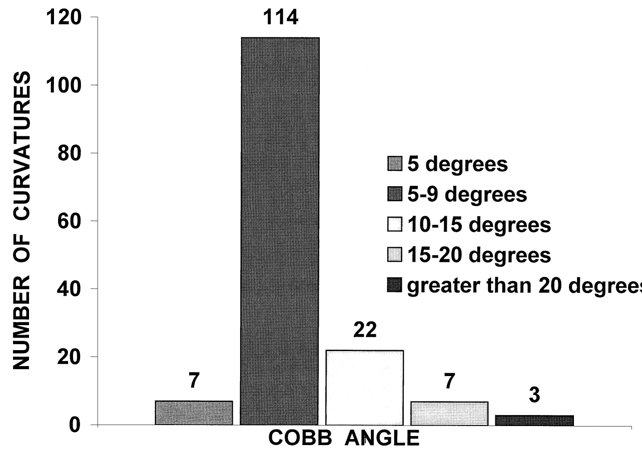

Figure 5. Distribution of curvatures according to Cobb angle.

Results

At the end of the scoliosis screening test, 156 pupils were found positive as a result of the FBT (true- and false-positives), 421 as a result of Moire topography, 604 from hump A, 1007 from hump B, and 545 as a result of the scoliometer. With radiographic examination, 153 (5.66%) pupils with spinal deformity were detected, with an age range between 10 and 17 years (average, 13 years). There were 88 girl and 65 boy pupils. The Cobb angle ranged between 5° and 40° (average, 9°; Figure 5). Forty-three of the spinal curvatures were thoracic, 85 thoracolumbar, and 25 lumbar. Scoliosis (defined as a spinal curvature with a Cobb angle ≥10°) was found in 32 pupils, for a prevalence of 1.18%. For scoliosis cases the Cobb angle ranged between 10° and 40° (average, 15°). Among the scoliosis cases, double curvatures were identified in only 10 children.

False-Negative Findings

Taking into consideration all spinal curvatures recorded by radiography, the FBT test produced 51 false-negative results. This means that radiographic evaluation identified 51 children with various spinal deformities who were initially considered to be negative for deformities. Moire topography was positive in 50 of these children, and 42 had a positive humpogram. In one case of positive radiography, Moire topography was negative (a false-negative result for the Moire method). This pupil had a thoracolumbar curvature (5°) with positive humpogram and scoliometer measurements. Twelve (hump A) and 36 (hump B) false-negative humpogram measurements were also recognized. Finally, 27 false-negative results were produced with the use of the scoliometer.

For all scoliosis curvatures recorded by radiography, the FBT test produced five false-negative results. Moire topography was positive in all cases (0 false-negative results), whereas hump A, hump B, and scoliometer produced two, four, and three false-negative results, respec-

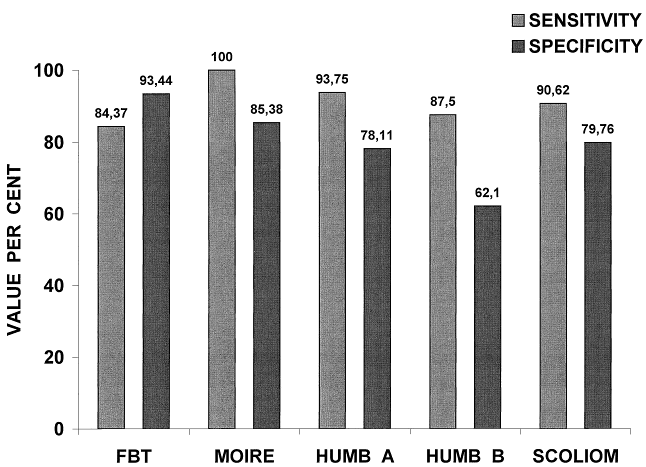

Figure 6. Sensitivity and specificity values for the four screening methods in detecting scoliotic curvatures (Cobb angle, ≥10°).

tively. Additionally, for scoliotic curvatures with a Cobb angle equal to or greater than 15°, FBT produced only one false-negative result (lumbar scoliosis of 15°), whereas Moire topography, hump A and scoliometer produced no false-negative results.

False-Positive Results

A high number of false-positive measurements was found with the use of all four screening methods. Concerning all spinal curvatures recorded by radiography, there were 54 false-positive results of the FBT. False-positive Moire results were disclosed in 269 cases, whereas false-positive humpogram measurements were 463 (hump A) and 890 (hump B). The scoliometer also produced 419 false-positive results.

On the basis of these results, the sensitivity and specificity values of the four screening methods in detecting scoliotic curvatures are shown in Figure 6. For the known low prevalence of scoliosis in this population (1.18%), the positive and negative prognostic values of the methods are shown in Figure 7.

Back-Shape Analysis Parameters and Cobb Angle

With the Moire method, there was a statistically significant correlation between Cobb angle and fringe asymmetry (paired t test; $t = 10.21$; $P > 0{,}001$) in all spinal curvatures. When the thoracic and thoracolumbar curvatures were isolated, a similar statistical correlation (paired t test; $t = 7.51$; $P \sim 0.001$, and paired t test; $t = 21.36$; $P \sim 0.001$, respectively) was found. The parameter H+D of the humpogram showed a statistically significant correlation with the Cobb angle only in thoracic spinal curvatures (paired t test; $t = 2.29$; $P \sim 0.05$). In contrast, there was no correlation between the angle of the scoliometer and the Cobb angle at all three levels of spine.

In Moire topography, when the asymmetry was two fringes or more, all the underlying scoliotic curvatures had a Cobb angle of 10° or more. For humpograms, when the parameter H+D was 10 mm or more, the underlying curvature was 10° or more. Similarly, a scoliometer angle of 8° or more reflected a curvature of 10° or more. If these numerical limits had been applied as selection criteria for radiographic evaluation at the beginning of the scoliosis school screening, an 89.4% reduction of referrals for radiography would have been achieved without missing any incidence of significant scoliotic curvature.

Interrater agreement in the assessment of Moire asymmetry was 85%, for humpogram deformities 88%, for scoliometer angles 80%, and for FBT 88%. It was estimated that the time spent on the Moire topography was 40 seconds per person, on scoliometer 20 seconds, on the humpogram 1 minute 10 seconds, and on the FBT 30 seconds.

Follow-Up Evaluation

At the end of the screening program, 3 pupils aged between 12 and 14 years with curvatures greater than 20° (two low thoracic and one thoracolumbar) were advised to begin nonoperative treatment with Boston braces. Two kept the braces on for 2 and 3 years with an increase of 8° and 10°, respectively, observed at final follow-up. Neither of these reported pain, cosmetic problems, or other functional problems. The last subject, who had a 40° thoracic curvature with progression underwent satisfactory surgical treatment 1 year later. It is worth stressing that this pupil had been examined and registered in the outpatient clinic of the hospital before the screening program.

Of the 121 curvatures with an initial Cobb angle less than 10° only 44 (35.8%) progressed (a Cobb angle difference of at least 5° in more than one examination) with an increase ranging between 5° and 10° (average, 8°), whereas in 18 (14.9%) a decrease of the Cobb angle was observed. None of these needed treatment other than observation and physiotherapy. Of the 29 curvatures with an initial Cobb angle of between 10° and 20°, 14

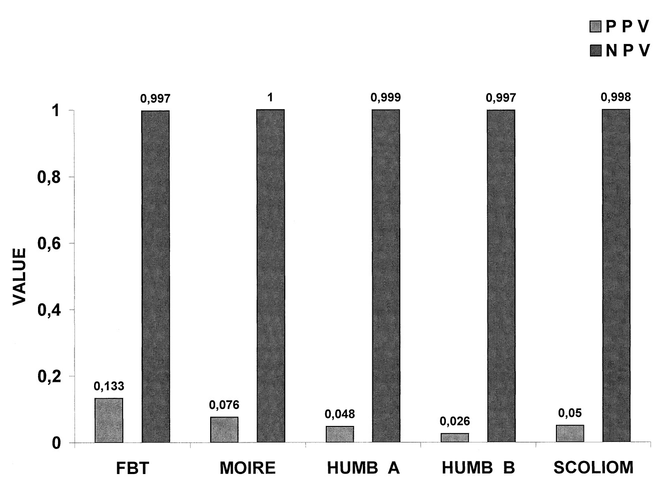

Figure 7. Positive and negative predictive values for the four screening methods in detecting scoliotic curvatures (Cobb angle, ≥10°).

(48.3%) progressed with an increase ranging between 5° and 14° (average, 10°). In 2 (6.9%) curvatures (10° and 14° respectively), a decrease of the Cobb angle was observed. Observation and physiotherapy were also the only treatments applied in all the pupils of this group except one, who, because of progression of the deformity, was successfully fitted 18 months later with a Boston brace, worn for 3 years.

Discussion

The value and efficacy of widespread school scoliosis screening has been questioned in recent years. The supporters of scoliosis screening argue from the clinical point of view that school screening tests provide early detection of spinal deformities, change the natural history of the disease, and have significant effects on morbidity and mortality.[31] The opponents argue that the cost of school screening outweighs its benefits and that conventional screening methods pose methodologic problems and are too sensitive, resulting in an unacceptable number of false-positive findings.

The Scoliosis Research Society and the American Academy of Orthopaedic Surgeons, in a joint statement first issued in July 1984 and revised in October 1987 and July 1992, attempted to endorse the principle of school screening for scoliosis.[4] Despite these efforts, the issue still remains controversial, and the literature reports varied and conflicting views about the efficacy and efficiency of mass screenings. The concept of screening as a means of early diagnosis has been generally supported by orthopedic surgeons and medical practitioners, but it has always been criticized by epidemiologists[12] for failing on the basis of many methodologic criteria. The United States Preventive Services Task Force[33] published a report stating they were unable to make a definite recommendation either for or against scoliosis screening because of insufficient scientifically based evidence.

In this article, the issues of accuracy, effectiveness of screening methods, and long-term clinical implications of school screening for scoliosis were examined in a closed population. In general terms, it is important that the methods used for screening a healthy population for early signs of a rare serious disease such as scoliosis show high sensitivity and negative predictive values. False-negative results are not acceptable; their existence is a principal error and the equivalent of a complete failure of the screening procedure. However, during a screening procedure, a moderate number of false-positive results are acceptable. The predictive values of a test depends on the prevalence of the abnormality in the population tested, and, more important, the more uncommon the true abnormality is the more certain it is that a negative test result indicates no abnormality.[2]

Although radiography safely identifies spinal deformities, its use in a school screening test for scoliosis is unethical. The hazard and the cost of radiography are two main reasons that explain all the attempts to develop other methods of scoliosis detection and documentation. The methods of back-shape analysis are relative easy, quick, cheap to perform, and do not pose any hazard for the growing child. Despite the publication of numerous articles about all aspects of the application of back-shape analysis methods for the detection of scoliosis, the sensitivity and specificity values are not known, and, more important, the number of false-negative results of these methods is unknown. It is not possible to estimate accurately the number of false-negative results from these methods unless the entire screened population is exposed to radiographic evaluation.

The current study presented a unique opportunity because of the availability of complete radiographic data for all the population screened because of the concurrent implementation of a routine widespread screening test for lung diseases. In this way, despite the possibility of missing a small number of lumbar curvatures, a reliable estimation of the parameters used by statisticians to compare screening methods was possible. For the screening of scoliosis in 1987, the FBT test and the back-shape analysis methods of Moire topography, the humpogram, and the scoliometer were used. These were the most commonly used methods for scoliosis screening at that time, with extensive literature support.

Moire topography had the highest sensitivity and negative predictive values with no false-negative results in screening for scoliotic curvatures. It is important to state that FBT showed low sensitivity and negative predictive values and a high number of false-negative results. Humpogram and scoliometer sensitivity and negative predictive values were also superior to those of FBT. According to these findings, the FBT is unsafe as a single screening method for the detection of scoliosis. Surprisingly, since its first report in the literature[1] the FBT has often been used by orthopedic surgeons as a single diagnostic tool for identifying scoliosis at their outpatient clinics. Moreover, most of the reported results of screening tests for scoliosis are based mainly on clinical examination.[14,17,28] Other investigators have also criticized FBT for several reasons,[16] one being that a rib hump may be a normal finding in school children.[7] To the best of the authors' knowledge this study is the only one in which the false-negative results of FBT have been estimated accurately.[13]

All methods presented high specificity values and high false-positive results, with the FBT and the Moire topography showing a lower number of false-positive results than the humpogram and scoliometer. It has been reported in the literature that the drawback to Moire topography is its high number of false-positive results. Laulund et al[16] found 29% false-positive results for Moire topography and 18% for FBT. Csongradi and Bleck[9] also found 44% false-positive results for Moire topography. Because of the recognition of this problem and the meticulous use of these diagnostic procedures, significantly lower false-positive results were produced in the current study (6.48% for clinical examination

FBT, 14.44% for Moire topography, 21.62% for humpograms, and 20% for scoliometer).

The existence of a high number of false-positive results is a very serious problem that is observed in most reported mass school screening programs, resulting in the referral of a relatively large number of children who have screened positively and whose spines are ultimately found to be normal or to have inconsequential curves with no treatment requirement.[13] Such false-positive results are often followed up, with the patient subjected to repeated radiographs, even though they do not benefit from them.[34] The problem is not only an ethical one but also one of economic significance for the organized national health services. The problem of false positive results can be minimized by the screeners' performing a recheck screening or combining several screening methods. All positive findings should be rechecked separately on another day. Only after this recheck should those with positive findings be referred for treatment.[18] In most recently reported studies, a recheck screening is the rule.[28]

Accurate noninvasive measurements of spinal curvature are crucial in planning treatment and assessing curve progression in adolescent idiopathic scoliosis. All methods of back-shape analysis directly identify and record deformities of the trunk (hump) and not the actual spinal deformity. In the current study, an attempt was made to correlate back-shape analysis parameters with spinal deformity parameters such as the Cobb angle. It was found that Moire topography and humpograms can indirectly estimate, in a reliable way, the Cobb angle in spinal deformity. The statistical correlation was strong when the curvatures were located at the thoracic and thoracolumbar levels only. No correlation between the scoliometer angle and the Cobb angle was found. In contrast, other investigators have found such correlation for the scoliometer[21] especially when complex mathematical formulas are used.[15]

The prevalence of scoliosis varies from 1% to 21% because of the different criteria used for the detection and diagnosis of scoliosis.[6] The prevalence found in the current study was 1.18% for deformities equal to or greater than 10°. These figures are comparable to those found in other regions of the country.[28]

Overreferral is one reason for the wide variability in the reported incidence of scoliosis in schoolchildren. It clearly results in needless expense, overuse of radiography, and overtreatment, and there is obviously a need for a more effective and specific screening method. Thus, the determination of specific criteria for those children at risk is of paramount importance. Because it is accepted that scoliosis equal to or greater than 10° (Cobb's angle) must be under observation and that progressive scoliosis between 20° and 30° (Cobb's angle) must be treated, the authors tried to identify cutoff limits of back-shape analysis parameters that could preclude a curvature of at least 10°. In this study three cutoff limits were isolated: The asymmetry of two Moire fringes, the deformity (D+H) = 10 mm on the humpometer, and the 8° angle on the scoliometer. If any of these three factors is identified, then, without radiologic examination, it can be concluded that the Cobb angle is equal to or greater than 10°. If these limits had been applied in the initial sample, the need for radiologic examination would have been eliminated or reduced in 89.4% of cases.

In a recent study,[14] in which a combination of FBT and scoliometer was used as the screening method, an attempt was made to produce such cutoff limits for further referral. Although by selecting angles of trunk rotation larger than 5° as the criteria for referral for radiography the positive predictive value increased, the investigators concluded that the optimal cutoff point for referral when using the scoliometer in school screening of scoliosis is still difficult to determine.

All the methods that were used in the current study were simple and fast. However, there was a percentage of personal errors. The authors recommend that at least two independent examiners participate in such screening programs. Records can be kept for all the methods used, except the FBT. Moire topography especially, with its photographic records,[35] allows for reliable comparisons and objective evaluations.

The majority of scoliotic curvatures recorded in this screening program had a Cobb angle of less than 10°. Although approximately half of these progressed, their progression was not clinically important (except for one pupil); no treatment other than observation was necessary, and there were no significant cosmetic or functional problems. The authors are not convinced that the minor curvatures in the study benefited from early detection and 10-year follow-up observation. If they had been left undetected and unregistered, very few of them would have attended the outpatient clinic of the County Hospital because of cosmetic or functional problems or pain. In total, four pupils needed actual orthopedic treatment. Nonoperative treatment was begun immediately for two of them after the completion of the screening program and for one 18 months later because of the progression of the deformity. It must be stressed that this last child, who eventually underwent surgical treatment, had been registered in the outpatient clinics before the initiation of the screening program.

In the light of these findings, the use of routine, widespread school screening tests for scoliosis must be questioned. The authors expect that adequately designed studies with larger numbers of subjects will support the current findings in the future.

In conclusion, FBT cannot be safely used as a single screening method for scoliosis, owing to the high number of false-negative results. However, back-shape analysis methods (such as Moire topography, scoliometer, and humpogram) can detect scoliosis early with great diagnostic accuracy and can lead to a reduction of referrals and radiologic examination. The widespread use of school screening tests for early scoliosis detection is not supported by the findings of this study.

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