A Population-Based Study of School Scoliosis Screening

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In the United States, 26 states mandate school scoliosis screening.1 The US Preventive Services Task Force assessed available data for scoliosis screening but reached no conclusions due to the lack of randomized controlled trials and observational studies of the outcomes of US screening programs.1–2 Supporters of scoliosis screening argue that simple screening tests with adequate sensitivity and specificity exist and that these programs are necessary to identify scoliosis early in its natural history, when nonsurgical intervention is possible.1–9 Opponents emphasize the low incidence of scoliosis requiring treatment, the resulting low positive predictive value (PPV) of screening programs, and high numbers of children who would be referred for further evaluation.10–18

Unfortunately, many of the arguments for and against school scoliosis screening in the United States are based on mathematical models derived from small empirical studies. The diagnostic sensitivity and specificity of a single scoliosis screening test using the scoliometer have been measured.13 However, the effectiveness of scoliosis screening is best determined by evaluating the complete school screening program, including the sensitivity and PPV and reproducibility of the series of screening tests for scoliosis diagnosis and treatment.10–19 Without program outcomes data, it is difficult to assess the value of maintaining school scoliosis screening programs. To help fill this gap in knowledge, we evaluated the outcomes of a school scoliosis program in Rochester, Minn.

METHODS
Setting
Rochester is a predominantly white, middle-class metropolitan community of 70,000 (1990 census) with 1 public and 2 private school systems. Collectively, the schools serve approximately 1000 students at each grade level.

Sample
All children attending public or private schools in Rochester who entered kindergarten in 1979, kindergarten or
first grade in 1980-1981, or first grade in 1982 and who remained in the Rochester schools for at least 3 of the yearly school scoliosis screening tests (beginning in grade 5, first year of screening 1984-1985) were included in the cohort. Children were followed up to age 19 years or until they left the school district (latest follow-up, 1994). Children who were home-schooled (n = 9) were not included.

**Screening Program**

All Rochester public and private schools participated in the same scoliosis screening program. Examinations were conducted by public health nurses hired by the school districts for this purpose. Boys and girls in grades 5 through 9 were screened yearly during physical education class periods. Boys were asked to disrobe to the waist; girls were allowed to leave their bras in place. The back was inspected for asymmetry. The standard forward bending test was visually inspected for asymmetry. The leave their bras in place. The back was inspected for asymmetry. The standard forward bending test was visually inspected for asymmetry. The

**Measurements**

The results of the scoliosis screening for each child in the cohort were abstracted from the school health records. The information obtained from these records included demographic information for each child, the results of each scoliosis screening in grades 5 through 9, and the dates of any referral or watch letters sent to the parents. School records are maintained indefinitely at the central district office for any child who withdraws, transfers, or graduates; therefore, all children’s records were available for review.

All medical records of each child whose parents were sent referral or watch letters were identified using the record linkage system of the Rochester Epidemiology Project, which indexes the care provided by all local medical facilities for all residents of Rochester and Olmsted County. To identify all episodes of chiropractic care for these children, records of all chiropractic clinics in Rochester were searched for any care provided to any of the referred children and children whose parents received watch letters. For each child, data were collected for all medical and chiropractic visits from ages 8 to 19 years.

Data were abstracted from the identified medical and chiropractic records for each visit in which scoliosis, spinal curve, or school referral was mentioned. The abstracted data included the date and clinician specialty for all visits; any evaluations for spinal curvature, including full spine x-rays and the associated Cobb measurements used to quantify curvatures; recommendations for further follow-up; and dismissal from care or referrals made, as well as brace and surgery treatment data. The progression of any documented curve was recorded, including the greatest degree of curvature before the age of 19 years. Scoliosis treatment was the primary outcome of interest and included both spinal braces and spinal surgery. For comparability with recent indications for bracing and surgical treatment of scoliosis, any documentation of spinal curvatures of at least 20° and 40° or more was also recorded. For consistency with current orthopedic literature, a Cobb measurement on a standing full spine x-ray of more than 10° was used for a diagnosis of scoliosis.

Children in the cohort who were treated for or diagnosed as having scoliosis and were not identified through school screening were ascertained by searching the Rochester Epidemiology Project Diagnostic Index for all diagnoses of “scoliosis” or “rule out scoliosis.” The medical records of these children were also abstracted in detail. No similar index was available to identify children not referred from school but evaluated or treated by community chiropractors.

**Statistical Analysis**

The number of children who did not pass school screening at each grade level, the number of children who failed multiple times, the percent positive agreement with future screening results for children who failed at least once, the number of children who were seen for follow-up care, and the number of children diagnosed and treated for scoliosis were calculated. The cumulative incidence of scoliosis in the cohort was estimated by the Kaplan-Meier method, censoring children who left the community on the last dates of school attendance. The sensitivity, number needed to screen, and PPV of the school screening program for identification of children with various levels of scoliosis or who were treated for scoliosis by 19 years of age were estimated based on all available data from community medical records.
tive for scoliosis, (2) positive for scoliosis in the same proportion as those who were evaluated, and (3) all positive for scoliosis.

The study protocol was approved by the institutional review boards of the Olmsted Medical Center, the Mayo Clinic, and the school boards of the public and private schools in Rochester.

RESULTS

The school records for 2934 children entering school in 1979-1981 were reviewed. Of this group, 689 (23.5%) left the school district before they entered seventh grade and were therefore eligible for 2 or fewer school scoliosis screening tests. Three children were noted to have been diagnosed and treated for idiopathic scoliosis prior to the first school screening in fifth grade and were not screened. The remaining group of 2242 children included 92 (4.1%) children (43 boys [47%], 49 girls [53%]) who were referred 1 or more times for further evaluation of possible scoliosis. The parents of another 328 children (14.6%) were sent watch or ninth-grade notification letters (Figure).

For many children, the results of screening tests varied from year to year (Table 1). For example, in the seventh-grade screening, 9 children failed screening, 8 of whom failed for the first time. Of the 9 children, 7 were screened in subsequent years and 2 failed again. The percent positive agreement across consecutive years of screening varied from 7% to 30% with no pattern of increasing or decreasing percent positive agreement with the next subsequent test was seen over the grades 5 to 9.

Medical or chiropractic records could be found for all of the 92 children referred for additional evaluation. Sixty-eight (74%) of the 92 children had mention of scoliosis evaluation in 1 or more medical records. Of the 68 having 1 or more visits for scoliosis evaluation, 51 (75%) had at least 1 standing x-ray of the spine. Twenty-three of the 68 were dismissed from scoliosis care after a single physician visit. The remaining 45 were treated or followed up. By 19 years of age, 27 (29%) of the 92 referred children (or 40% of the 68 children with scoliosis-related visits) were known to have scoliosis with curves of more than 10° and 5 (5.4%) were treated (Table 2 [column 1]).

Of the other 328 children whose parents were sent watch or ninth-grade letters, all but 3 were found to have medical or chiropractic records, and 62 (19%) had notation of a scoliosis assessment. By 19 years of age, none of these children were treated, and 5 had documented scoliosis of more than 10° (Table 2 [column 2]).

In the school health records, 3 children (1 boy and 2 girls) were noted as having idiopathic scoliosis identified prior to the first school screening. Another child was noted to have congenital scoliosis treated before entering kindergarten and was not included in the analysis. Of the children with idiopathic scoliosis, 2 were treated with a brace and surgery, and 1 was treated with a brace only. These children were included in the calculations of community cumulative incidence and sensitivity of the school screening program.

An additional 9 children in the cohort were found to have had documented visits for scoliosis evaluation, and 6 were found to have scoliosis. None were in the groups whose parents received referral or watch letters. The evaluation of scoliosis was initiated by a physician during a visit for another reason in 4 children. Visits of the other 5 children were reported to be in response to school referrals but no parental notification was documented in the school health records. These 9 children included 1 girl who was treated...
with a brace (at 12 years of age) and surgery (at 13 years of age) for scoliosis identified during a physician visit. She passed scoliosis screening episodes in grades 5, 6, and 7. In addition, 5 other children had a diagnosis of scoliosis, with curves of 11° to 19°, and 3 with curves of 20° to 39°.

By 19 years of age, the Kaplan-Meier cumulative incidence of diagnosed scoliosis in the entire cohort, determined both from school screening and community identification, was 1.8% for curves more than 10° (95% confidence interval [CI], 1.2%-2.3%); 1.0% for curves of at least 20° (95% CI, 0.6%-1.5%); and 0.4% for curves of 40° or more (95% confidence interval, 0.1%-0.6%). The cumulative incidence was statistically significantly higher for girls than boys for curvature was statistically significantly 0.1%-0.6%). The cumulative incidence of diagnosis of adolescent idiopathic scoliosis in the entire cohort, determined both from school screening and community identification, was 0.56 (95% CI, 0.38-0.74) (5/9: 9 children were treated; 6 children in the cohort who were screened and subsequently treated for idiopathic scoliosis was 0.56 (95% CI, 0.38-0.74). The school screening program identified 5 (83%) of the 6 children in the cohort who were screened and subsequently treated for scoliosis. Among the 92 children having a positive screening examination, 5 were treated. The PPV of the school program was 0.05 (95% CI, 0.048-0.052) (Table 3). The sensitivity and PPV were higher for the presence of scoliosis of at least 20° or 40° or more. Since not all referred children were evaluated, a sensitivity analysis was done to estimate the potential range of values for sensitivity and PPV (Table 3). The number needed to screen to identify a child who subsequently received treatment was 448 (2242/5); to identify a child with a curve of at least 20° by 19 years of age, the number needed to screen was 140 (2242/16). The number of screening examinations needed to identify each child treated was 2234 based on the multiple tests children received in grades 5 through 9.

**Comment**

In this cohort of 2242 children, annual scoliosis screening identified 92 children who were referred for further evaluation of possible scoliosis. An additional 328 parents were notified of possible abnormalities. A total of 9 children were treated for scoliosis, 5 (56%) of whom were identified in the school screening program, and 3 were identified prior to the first school screening. During the 5 years of screening, positive screening test results varied from one year to the next and the low prevalence of treated scoliosis resulted in a low PPV (5%) for the program and a high number needed to screen to identify 1 child needing treatment (448). The lack of evaluation of 24 of the referred children may have falsely lowered the PPV; however, it is unreasonable.

### Table 1. Stability of Screening Results From Grades 5 Through 9

<table>
<thead>
<tr>
<th>Status</th>
<th>Grade 5</th>
<th>Grade 6</th>
<th>Grade 7</th>
<th>Grade 8</th>
<th>Grade 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total failed</td>
<td>11</td>
<td>14</td>
<td>9</td>
<td>35</td>
<td>28</td>
</tr>
<tr>
<td>Failed for first time</td>
<td>11</td>
<td>11</td>
<td>8</td>
<td>30</td>
<td>27</td>
</tr>
<tr>
<td>Ever screened again</td>
<td>10</td>
<td>13</td>
<td>7</td>
<td>29</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Failed next grade</td>
<td>3 (30)*</td>
<td>1 (8)*</td>
<td>2 (29)*</td>
<td>2 (69)*</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Failed ever again</td>
<td>4 (40)*</td>
<td>4 (23)*</td>
<td>2 (31)*</td>
<td>2 (7)*</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Received evaluation at that grade level</td>
<td>5</td>
<td>8</td>
<td>3</td>
<td>25</td>
<td>22</td>
</tr>
<tr>
<td>Treatment initiated at that grade level</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Ever treated†</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Ever progressed to 20°†</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Ever progressed to 40°†</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

*The percentages were calculated using only children who were screened again.
†Including only those failing for first time in this grade.

### Table 2. Number of Children With Identified Adolescent Idiopathic Scoliosis in a Population-Based Cohort: Comparison of School-Identified vs All-Identified Cases (N = 2245)

<table>
<thead>
<tr>
<th>Results by Age 19 y</th>
<th>Identified Following Referral From School Screening, No. (No. of Girls) (n = 92 Referred)</th>
<th>Identified Following Watch Letter Notification From School Screening, No. (No. of Girls) (n = 328 Notified)</th>
<th>Identified Outside School Screening Program, No. (No. of Girls) (n = 9)</th>
<th>Total in Cohort, No. (No. of Girls)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cobb measurement</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11° - 19°</td>
<td>11 (6)</td>
<td>3 (3)</td>
<td>2 (2)</td>
<td>16 (11)</td>
</tr>
<tr>
<td>≥20° - 39°</td>
<td>10 (8)</td>
<td>1 (0)</td>
<td>5 (4)</td>
<td>16 (12)</td>
</tr>
<tr>
<td>≥40°</td>
<td>6 (3)</td>
<td>1 (1)</td>
<td>2 (1)</td>
<td>9 (5)</td>
</tr>
<tr>
<td>Treatment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brace only</td>
<td>3 (2)</td>
<td>0</td>
<td>1 (1)</td>
<td>4 (3)</td>
</tr>
<tr>
<td>Surgery only</td>
<td>1 (0)</td>
<td>0</td>
<td>0</td>
<td>1 (0)</td>
</tr>
<tr>
<td>Brace and surgery</td>
<td>1 (1)</td>
<td>0</td>
<td>3 (2)</td>
<td>4 (3)</td>
</tr>
</tbody>
</table>

*Includes those not identified in school, including 3 prior to first school scoliosis screening and 6 identified outside school screening.
able to assume that any effectiveness study will have 100% compliance with referred recommendations. If the children who were not evaluated were treated for scoliosis in the same proportion as those referred and evaluated, the PPV would change little, increasing to 7%.

Our reported community cumulative incidence of diagnosed scoliosis is similar to that reported in the literature. In a study of the natural history of untreated scoliosis, the prevalence of spinal curves was 2.3% for 10° to 19°, 0.8% for 20° to 39°, and 0.1% for 40° or more at 18 years of age.25 Other reported prevalence rates range from 0.08% to 4.0% of adolescents, depending on the year of the study, the definition of scoliosis, the duration of follow-up, the sex and age of the children studied, and the country in which the study was completed.7,8,11,14,25-27 We assumed that the 17 children evaluated by physicians for scoliosis and dismissed from further evaluation without x-rays did not have scoliosis. If some of these children did have scoliosis, the true cumulative incidence of scoliosis would be greater than we estimate in this study. In addition, some of the 24 children who had no record of scoliosis evaluation may have had scoliosis as considered in the sensitivity analysis of the program (Table 3). It is unlikely that all of the 24 children not evaluated should have been treated for scoliosis. The most clinically reasonable estimate would be that these children have scoliosis requiring treatment in the same proportion as the 68 who had a physician evaluation. Under this assumption, the number of treated children would increase by 2, making the cumulative incidence of treated scoliosis 0.05 (11/2242). The low incidence of treated scoliosis led to the discontinuation of school scoliosis screening programs in several European countries.10,11,14,26

The rate of treatment for children treated in this study is also comparable to treatment rates (0.2%-0.4%) reported in other studies prior to 1995.14,15 Data from a recent randomized trial suggest that more children might be considered candidates for treatment today than during the time period of this study.23 Early brace therapy can slow progression in the 20% to 35% of girls who would have progression of their moderate (25°-40°) curves.25-28 It is not possible to know exactly how many children in this study would be eligible for treatment by current recommendations. The estimated cumulative incidence of diagnosed scoliosis with curvature of at least 20° suggests that the upper limit would be approximately 1.0% (95% CI, 0.6%-1.5%). This is likely to overestimate the number eligible for treatment because some of the children were skeletal mature when diagnosed or had stable curves of more than 20° and would not be candidates for bracing. The cumulative incidence of children who might receive treatment for scoliosis is likely between the 0.4% treated and the 1.0% with curves of more than 20°.

The marked variability of the screening results deserves special attention.15 Since the scoliometer was not introduced into this community until the 1986-1987 school year, the criteria for screening failure changed between the 1985-1986 and 1986-1987 school year. However, all children were screened in grades 7, 8, and 9 with the scoliometer and the variability in those years is as marked as the variability seen in grades 5 and 6 (Table 2). Some of the variability could have been due to the screener’s knowledge of prior screening results or knowledge of ongoing evaluation and treatment occurring outside the school setting. Treated leg length differences or resolving kyphosis or round back, which were not noted on the school health record but which allowed the children to pass future screening tests, may account for some of the variability. Some children who ultimately proved to have scoliosis by physician and x-ray evaluation had negative scoliosis screening tests following their first screening failure and referral. The accuracy of screening assessments in relation to periods of rapid growth velocity deserves further evaluation, as do our results on the performance of the series of screening tests.

Not all children who were referred had scoliosis mentioned in their medical or chiropractic records. The rate of follow-up after receiving a scoliosis referral letter (74%) is high but lower than the 92% follow-up rate documented in the same population after referral for failed school vision screening.29 This apparent differential rate of compliance with school recommendations should be further evaluated since adequate follow-up is essential for success of a screening program.

In this program, overidentification was compounded by the use of ninth-grade and watch letters that informed parents of screening results insufficient to meet referral criteria. These letters resulted in visits for 62 children who never failed a screening test. None

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**Table 3. Estimated Range of Sensitivity and Positive Predictive Values (PPVs) for Program of Screening**

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Sensitivity</th>
<th>PPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment by age 19 y</td>
<td>0.56</td>
<td>0.05</td>
</tr>
<tr>
<td>Curves of ≥20° by age 19 y</td>
<td>0.64</td>
<td>0.17</td>
</tr>
<tr>
<td>Curves of ≥40° by age 19 y</td>
<td>0.67</td>
<td>0.07</td>
</tr>
</tbody>
</table>

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of these children received treatment. The watch and ninth-grade programs were established at the request of parents. From the perspective of the school personnel who had no community follow-up data, a program that notifies 10% of parents regarding a potential health problem may seem to be a valuable addition to the school screening programs. These data suggest the watch and ninth-grade letter programs should be discontinued.

Our results may not be generalizable to the entire United States, but may represent a unique scenario for assessing the value of school scoliosis screening. No other studies of school scoliosis screening have provided outcomes data and it is unlikely that a randomized controlled trial of school scoliosis screening will ever be carried out. The Rochester school districts’ student populations are more than 90% white with income and parental education levels higher than the state and national norms. The rate of scoliosis is reported to be higher in the white community than the African American community, suggesting that the screening may appear to be more effective in Rochester than it would in a racially mixed community. In Rochester, medical care is readily available, including the practice of 3 pediatric orthopedic surgeons, and more than 85% of families in the community have health insurance. In addition, the community was sufficiently concerned about the issue of scoliosis to request the watch and ninth-grade letter programs. This suggests a high level of awareness and ability to obtain recommended follow-up evaluation and care. This should provide an excellent environment to evaluate school scoliosis screening. Conversely, the same unique community characteristics may have facilitated the detection of children before or outside of the screening program, making the screening program appear less useful than it may be in more economically diverse or underserved communities where disadvantaged adolescents often lack access to medical care services that are readily available in this community. Students in disadvantaged communities may lack the opportunity to be identified outside a school screening program.

School scoliosis screening identifies some children who ultimately receive treatment but refers many more who do not. While it is not known how many children would be identified as having scoliosis without school screening, a randomized controlled trial of scoliosis screening is unlikely to be completed in the United States. Therefore, individual communities and state legislators will need to decide what is appropriate and feasible for their schools based on the best available data.

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**REFERENCES**