Feature Article

Risk Factors for Idiopathic Scoliosis: Review of a 6-Year Prospective Study

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ABSTRACT

This study identified factors associated with the prevalence of idiopathic scoliosis and curve evolution in schoolchildren from northwestern and central Greece. A total of 85,627 children aged 9-15 years were screened for scoliosis. A subset of children with curves of at least 10° underwent clinical and radiographic follow-up. The total population screened and the cohort followed for curve progression were evaluated according to factors associated with curve evolution.

The prevalence of scoliosis was 1.7%, with most cases appearing at ages 13 and 14 years and small scoliotic curves (10°-19°) being most prevalent (prevalence 1.5%). Prevalence was associated with gender; age; and magnitude, apex, and direction of the curve. Progression of the curve occurred in 14.7% of 839 children, while 27.4% demonstrated spontaneous improvement of at least 5°. A high risk of curve progression was associated with the following: sex—girls, curve pattern—right thoracic and double curves in girls and right lumbar in boys, maturity—girls before the onset of menses, age—time of pubertal growth spurt, and curve magnitude—curves ≥30°. Although only a small percentage of scoliotic curves undergo progression, the pattern of the curve according to curve direction and the sex of the child plays a significant role in the ability to identify which curves will progress.

Although several procedures are now available for effective conservative and operative treatment of scoliosis, the most effective management is based on early detection. In this regard, school screening is still considered by many orthopedic surgeons as a useful tool for identifying children with scoliosis. Moreover, many believe it provides information on which children may be at high risk for developing the disease without the screening procedure being considered a diagnostic test. The epidemiologic value, however, of school screening programs has spurred considerable debate.

On the other hand, a major concern of orthopedic surgeons in managing children with scoliosis of a minor curvature is how many and which curves will progress to severe deformities requiring treatment. In this regard, screening has been considered helpful not only for identification of children who may have scoliosis, but also for providing information on the course of the disease. The vast majority of children show no spinal deformity, and of the scoliotic curves detected through school screening, only a percentage progress to clinical significance. The prevalence reported in the literature varies greatly. Although most authors agree the accurate identification of curves destined to progress requires a clear understanding of the natural history of idiopathic scoliosis, it is unclear to what extent the various factors that have been associated with curve progression can be used in predicting the course of the natural history of the scoliotic curve. As a result, definitive guidelines have yet to be established that can assist the surgeon in assessing the risk of progression for each child.

This study assessed which factors can be taken into account for predicting curve behavior to elucidate the natural history of scoliosis. This was done by reviewing the results of 6 years of follow-up of a school screening program and assessing the distribution of various parameters according to prevalence rate and curve progression in untreated scoliosis.

MATERIALS AND METHODS

Study Design

The school screening program of the Spine Unit of the Department of Orthopedic Surgery of the University of Ioannina Medical School has been

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TABLE 1  
Geographic Distribution of Study Population

<table>
<thead>
<tr>
<th>Geographic Area</th>
<th>No. Children Screened</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thessalia</td>
<td>38,044</td>
</tr>
<tr>
<td>Epirus</td>
<td>21,415</td>
</tr>
<tr>
<td>Etolo-Akarnania</td>
<td>16,743</td>
</tr>
<tr>
<td>Ionian Islands</td>
<td>6699</td>
</tr>
<tr>
<td>Northern Epirus</td>
<td>2721</td>
</tr>
<tr>
<td>Total</td>
<td>85,622</td>
</tr>
</tbody>
</table>

asessed. In the final stage of the study, curve progression was studied from multiple, consecutive follow-up examinations of 839 children diagnosed with idiopathic scoliosis of at least 10° from the major geographic area of the University of Ioannina for an average of about 4 years.

With the permission of the Hellenic Ministries of Education and Health, the administration of the school districts were contacted, and the schools and teachers were given a detailed description of the importance and methods of scoliosis screening. Permission also was obtained from parents with a letter that explained the intentions and procedure of the examination as well as the clinical importance of early detection.

Scoliosis screening teams, consisting of a senior orthopedic surgeon and staff member, an orthopedic resident, a nurse, and a medical student, were organized and trained in screening methods. Before the actual school screening took place, individual student forms were forwarded to the schools for students to fill in biographical information. Children who were diagnosed previously and had been or were currently under treatment for scoliosis were not examined in the initial school screening but were included in all other aspects of the study.

School Screening Test

Screening took place in physical education classes. Boys and girls were examined separately in their familiar class groups. Boys were asked to wear shorts, and girls wore shorts and a bra or a loose T-shirt that could be lifted during examination. Small groups of about 20 children were admitted into the examining room. Students brought their own data form with the biographical section completed.

First, the child’s physical attributes were recorded by an orthopedic resident or medical student. The child then proceeded to the senior orthopedic surgeon, who examined for spinal and other deformities. The child was asked to stand in an erect, relaxed position to record any abnormality in the upper and lower extremity, including lateral deviation of the spine; asymmetry of the waist, shoulders, or scapulae; and limitation in joint motion.

Next, the Adams forward bending test was performed; the child was asked to bend forward, allowing the arms to hang freely with palms opposed in a relaxed manner. The exposed back of the child was viewed from the head and from the side in the forward bending position.

Parameters recorded included: 1) biographical information (name, date of birth/age, address, parents’ age and occupation, and number and gender of siblings), 2) physical measures (hair and eye color, body frame [large, medium, or small], age at menarche in girls and rough indication of pubertal stage in boys as indicated by the degree of pubic/body hair, weight, standing and sitting height, and arm span length), and 3) spinal screening (rib/lumbar humps, shoulder/hip discrepancies, and torso/spinal imbalance).

Rescreening and Radiographic Evaluation

Positive signs for scoliosis included asymmetric shoulder levels, scapular prominence, unequal distance from arms to flanks or lower limb inequality in the standing position, or lateral deviation of the spine in the Adams forward bending test. Children with a positive screening were reevaluated by a senior orthopedic surgeon to confirm criteria for referral. Thus, children suspected of scoliosis were requested to present themselves to the team for reevaluation that same afternoon at a local clinic.

At reevaluation, the child was submitted to a second forward bending test. The examiner compared the two sides of the child’s torso at both the thoracic and lumbar areas. If any difference in height between the two sides was noted, it was measured using a level plane and ruler. A difference >5 mm was considered a positive bending test. It should be noted that although most surgeons agree no differences exist between screening in the sitting
and standing position in terms of lower limb equalities resulting from hamstring shortening, the bending test in a sitting position with the knees bent has been reported to avoid false suspicion of rotation of the spine.11

The child was referred for radiographic evaluation if the examiner confirmed a positive Adams test with a difference >5 mm between the two sides at the thoracic or lumbar area or the presence of any of the physical signs noted above. Thus, criterion for radiographic evaluation was a positive finding by the examiner in a second recheck screen. Only after a recheck were positive cases referred for standing posteroanterior radiographs, which were taken and assessed immediately.

A curve measuring ≥10° using the Cobb Method was defined as a structural scoliosis according to the Scoliosis Research Society criteria.11 In cases in which there was any doubt about whether a curve was structural, lateral radiographs were taken. Only children with structural curves ≥10° were included in the study.

Management

The course of treatment for each child was based on the magnitude of the scoliotic curve. Children who had curves between 10° and 19° were advised to have periodic clinical observation every 4-6 months, while children who had curves between 1° and 9° (particularly if in a high-risk group, eg, premenarche) were advised to have periodic clinical observation every 12 months. Children who were radiographically negative were excused.

Of the 1436 children identified with scoliosis, 170 were treated conservatively and 11 underwent surgical management. The remaining children were referred for periodic clinical observation according to the size of the scoliotic curve at orthopedic clinics in the child’s geographical area. The analysis on curve progression was restricted to untreated scoliotic curves or up to the time that treatment was initiated for those undergoing treatment.

| TABLE 2 |
| Distribution According to Age and Curve Pattern |

<table>
<thead>
<tr>
<th>Age (y)</th>
<th>No.</th>
<th>Thoracic Right</th>
<th>Left</th>
<th>Lumbar Right</th>
<th>Left</th>
<th>Thoracolumbar Right</th>
<th>Left</th>
<th>Double</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;9</td>
<td>58</td>
<td>5</td>
<td>1</td>
<td>3</td>
<td>13</td>
<td>11</td>
<td>19</td>
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<td>10</td>
<td>168</td>
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<td>5</td>
<td>7</td>
<td>42</td>
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<td>9</td>
<td>16</td>
<td>57</td>
<td>29</td>
<td>48</td>
<td>34</td>
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<td>275</td>
<td>42</td>
<td>10</td>
<td>24</td>
<td>70</td>
<td>40</td>
<td>51</td>
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<td>50</td>
<td>14</td>
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<td>94</td>
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<td>11</td>
<td>20</td>
<td>43</td>
<td>22</td>
<td>29</td>
<td>24</td>
</tr>
</tbody>
</table>

Follow-Up Study of the Natural History of Progression

The curve progression study program has been described previously.3 The natural history of scoliosis was studied in 839 children of the 1436 children with idiopathic scoliosis identified from the schoolchildren screened in northwestern and central Greece. The children assessed for curve progression in the present study were from the geographical area of the University Hospital, allowing for multiple, consecutive follow-up clinical and radiographic evaluations.

Of the 839 children who underwent follow-up for curve progression, 72.5% were girls. The median age was 13 years for both genders. In the majority of cases (64.5%), the magnitude of the scoliotic curve at the initial evaluation was 10°-14° and the apex of the curve was thoracic curve (35.5%) or lumbar (30.9%).

Each child with scoliosis underwent clinical and radiographic follow-up for 2-6 follow-up visits for an average of a little over 4 years (range: 2.5-5.4 years). Children with curves >30° underwent follow-up for at least 2 visits up until the initiation of treatment, after which they were excluded from the study.

Progression of the curve was defined as an increase of ≥5° as measured by the Cobb method over two or more visits. Factors that were assessed for association to progression of the curve included sex, age, maturity (menarche for girls), curve pattern, and curve magnitude.

RESULTS

Prevalence

Seven percent of the children had at least one positive clinical sign at their initial screening. The prevalence for radiographic structural scoliosis ≥10° was 1.7%, with the prevalence for scoliosis in girls being higher than for boys (2.6% versus 0.9%, respectively). The mean age at screening was 12.4 years.

The prevalence of scoliosis varied according to age group. Only 0.07% of the children aged 9 years presented with scoliosis, while by age 10 years, 0.2% of the children had scoliosis. The greatest prevalence of scoliosis cases was observed at age 14 years, with 0.4% prevalence. Moreover, the prevalence for each age group varied according to the apex of the curve and age (Table 2).

The prevalence of scoliosis also varied according to the degree of magnitude of the curve. The prevalence of scoliotic curves 10°-19° was 1.5%; 20°-29°, 0.2%; 30°-39°, 0.03%; and >40°, 0.014%. The sex ratio for the different sizes of the scoliosis curves varied with the size of the curve (Table 3). The preponderance of girls increased noticeably with the increasing magnitude of the scoliosis curve, with the exception of curves >40° where the ratio approaches 1:1.

Single curves occurred approximately seven times more frequently than double curves. Thoracolumbar curves followed by lumbar curves were the most common pattern of scoliosis identified. Overall, 18.2% of the curves were thoracic, while 34.4% of the
of the scoliotic curve at the first visit was smaller in those children who demonstrated improvement (mean: 11.7° and 13.6° for boys and girls, respectively) compared to those who showed progression of the curve (mean: 16.7° and 16.4° for boys and girls, respectively).

**Factors Related to Curve Progression**

The incidence of progression in boys was significantly less than in girls ($\chi^2, P<.05$). The sex difference in progression was most notable in children who showed curve progression between 5° and 9° in magnitude (54.5% for girls and 9.8% for boys) ($\chi^2, P<.05$). On the other hand, the difference between boys and girls observed for curves that progressed between 10° and 14° (8.9% for girls and 4.1% for boys) or >15° (6.5% for girls and 2.4% for boys) was not statistically significant.

The incidence of progression also varied with age. Both boys and girls demonstrated a small but notable peak in the incidence of progression at the time of pubertal growth spurt (11-12 years for girls and 14 years for boys). Of the girls with progressive curves (n=101), menarche had occurred in only 35.6%; in contrast, of the girls who showed improvement or remained stable (n=507), menarche had occurred in 52.3%.

The incidence of progression varied significantly according to the pattern of the curve, with double curves showing a higher incidence of progression (21%), followed by thoracic (16.9%), lumbar (14.3%), and then thoracolumbar curves (10.1%). There was a notable difference in the incidence of progression between boys and girls for double and thoracolumbar curves (double curves: 8.3% versus 23.6% and thoracolumbar curves: 4.9% versus 12.9% for boys versus girls, respectively; $P<.05$).

The direction of the curve (left versus right) for each type also played an important role in curve progression, particularly when considered in association with the sex of the child. None of the left thoracic curves showed progression over the follow-up period, while the incidence of progression of right thoracic curves (overall mean: 22%) was as high as that observed for double curves (overall mean: 21%). Progression of right thoracic curves for boys and girls was 17.6% and 23.2%, respectively. While girls with right and to a lesser extent with left thoracolumbar curves showed a higher incidence of progression than boys, boys with right lumbar curves demonstrated a higher incidence of progression (27%) than girls (10%).

Left thoracic as well as left and right thoracolumbar curves were associated with a high percentage of curve improvement (38%, 47%, and 41%, respectively) (Table 5). Moreover, a large percentage of these patients (34%, 38%, and 39%, respectively) showed a decrease in the magnitude of the curve of $\geq$10°. Of the children who demonstrated complete spontaneous resolution of the scoliotic deformity, 41% had left thoracolumbar curves and 78.8% had an initial curve magnitude between 10° and 12°.

Overall, the greater the magnitude of the initial curve, the greater the incidence of progression. The increase in the percentage of patients showing progression was moderate for curves between 10° and 20° (11.9% to 20%, respectively). However, for curves $>30°$, the incidence of progression increased significantly (48%).

Although gender alone was associated with progression, no difference between boys and girls was observed in association with the magnitude of the curve. The incidence of progression did not appear to be significantly related to the magnitude of the curve according to the child's age, although the incidence of progression was associated with the curve magnitude according to the type of the curve.

The school screening program covered a large geographical region in northwestern and central Greece including isolated rural and dense urban areas. Of the children screened, 69.2% were from urban areas and 30.8% were from rural areas. Although 35% of the children identified with sco-
liosis were from rural areas and 65% were from urban areas, the incidence of progression was slightly higher in patients from rural areas (15.6%) compared to those from urban areas (13.6%) \( (P > 0.05) \).

No association between progression and parents’ age, number of siblings, hair or eye color, or height were observed.

**DISCUSSION**

The prevalence of scoliosis in schoolchildren in northwestern and central Greece was 1.7%, with the majority of cases appearing at ages 13 and 14 years and small scoliotic curves \( (10°-19°) \) being the most prevalent \( (1.5\%) \). Although this is similar to most previous reports,\(^6,10,12\) the distribution of other parameters associated with scoliosis appeared to be more variable. Moreover, significant individual variation was observed in the natural history of the scoliotic curves. Nonetheless, several factors could be identified that showed a noteworthy association with the course of curve development.

Although the present epidemiologic findings are similar to those of most previous reports,\(^5,6,10,12\) the differences noted indirectly support the hypothesis of a genetically related variation in the prevalence of scoliosis and the apex of the curve for different populations.\(^4\)

Specifically, the apex of the curve for the majority of the scolioses in the Greek population was thoracolumbar, followed closely by lumbar curves. This differs from the findings reported for study populations in Norway and Sweden where the proportion of single thoracic curves greatly outweighed that of all others.\(^2,13\)

In contrast, the predominance of thoracolumbar curves reported in California was greater than that observed in Greece.\(^12\) Double curves constituted <20% of the scolioses observed in the Greek population, which is similar to the findings of most studies.\(^2,12,13\)

In this study, left curves predominated overall. The left-to-right ratio, however, varied according to the location of the apex of the curve with the majority of thoracic curves being right and the majority of thoracolumbar and lumbar curves being left.

Although the association of progression and curve pattern observed in this study was compatible to previous findings,\(^5,14\) curve pattern along with the direction of the curve and the sex of the child together were found to play a more important role in assessing the risk for curve progression. Thus, left thoracic curves were never observed to progress, but rather showed spontaneous improvement.

On the other hand, the incidence of progression for right thoracic curves was as high as that observed for double curves. While both right and left thoracolumbar curves progressed more frequently in girls, right lumbar curves showed a much greater percentage of progression in boys. The latter is noteworthy, as it is the only case where boys were found to have a high incidence of curve progression.

The female-to-male ratios were intermediate to those reported for Sweden and California.\(^2,11\) While previous studies suggest the preponderance of females increases noticeably with the increasing size of the scoliosis curve,\(^2,5,12\) the observations of the Greek population \( (85,627 \text{ children}) \) indicated the preponderance of females increased with the degree of the curvature up to \( 30°-39° \). The prevalence of very large curves \( (≥40°) \) in boys and girls appeared to be approximately equal; however, the number of cases was small.

Gender also was related to the amount the curves progressed. Although girls showed a higher incidence of progression overall, the difference between boys and girls was more pronounced, with curves that progressed between 5° and 10°.

Previous reports have suggested a correlation between age and progression, with the incidence of progression decreasing as the child gets older.\(^4,14\) It has been suggested the progression of idiopathic scoliosis occurs at the time of the most rapid adolescent skeletal growth and the onset of puberty.\(^5\) A relatively small peak in progression was observed in girls around 12 years of age and in boys around 14 years of age, which appears to be associated with the pubertal growth spurt.\(^2\) The difference between boys and girls may be attributed in part to the observation that boys and girls at these ages differ greatly in their growth and development.\(^16\)

While age did not show a direct linear

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**TABLE 4**

**Distribution of Curve Patterns According to Curve Magnitude**

<table>
<thead>
<tr>
<th>Cobb Angle</th>
<th>No.</th>
<th>Thoracic Left</th>
<th>Thoracic Right</th>
<th>Lumbar Left</th>
<th>Lumbar Right</th>
<th>Thoracolumbar Left</th>
<th>Thoracolumbar Right</th>
<th>Double</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-19</td>
<td>1255</td>
<td>59</td>
<td>161</td>
<td>309</td>
<td>156</td>
<td>158</td>
<td>259</td>
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<tr>
<td>20-29</td>
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<td>23</td>
<td>16</td>
<td>8</td>
<td>43</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td>30-39</td>
<td>26</td>
<td>1</td>
<td>9</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>&gt;40</td>
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<td>0</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>5</td>
</tr>
</tbody>
</table>

**TABLE 5**

**Percent Incidence of Change for Different Curve Types**

<table>
<thead>
<tr>
<th>% Thoracic</th>
<th>% Lumbar</th>
<th>% Thoracolumbar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left</td>
<td>Right</td>
<td>Left</td>
</tr>
<tr>
<td>Progression</td>
<td>0</td>
<td>22</td>
</tr>
<tr>
<td>Stable</td>
<td>63</td>
<td>59</td>
</tr>
<tr>
<td>Improved</td>
<td>38</td>
<td>20</td>
</tr>
</tbody>
</table>
relationship with the incidence of progression, maturity as reflected by menses in girls was associated with progression of the curve. Specifically, curves that developed before menarche in girls had almost twice as great a risk for progression. This is consistent with the observation that curve progression often coincides with the onset of puberty and the appearance of secondary sex characteristics. Previous studies have shown a relationship between the incidence of progression and the Risser sign. The Risser sign, as a scale of ossification of the iliac apophysis, is considered an indirect measure of maturity.

The incidence of progression also increased somewhat with the size of the initial scoliotic curve. Previous studies have shown a direct relationship between progression and magnitude of the initial scoliotic curve, where the incidence of progression increased with an increase in curve magnitude. In the present study, only a moderate association was observed for curves up to 29° in magnitude. It is not surprising that since age and curve magnitude independently did not demonstrate strong correlation with progression, that the incidence of progression according to both age and magnitude also did not show a striking association, as has been suggested in previous reports.

It has been suggested that “The purpose of a screening test is to identify children who are at high risk of developing the disease and not to diagnose the disease.” As children with severe deformities are normally treated, it is unclear at what point curves stop progressing and stabilize. Nonetheless, several attempts have been made to identify features that may assist the orthopedic surgeon in predicting which scoliotic curves are at risk of progressing to the point of clinical significance, requiring active management.

Several studies have suggested the magnitude of the curve and the child’s age and maturity are related to curve progression in idiopathic scoliosis. On the other hand, only a few have suggested a relationship between progression and sex, family history, or pattern of the curve. Overall, the incidence of progression in different reports varies according to the criteria of progression, inclusion of patients undergoing treatment, and length of follow-up.

The incidence of curve progression found in this study (14.7%) is within the lower range of these reports where a higher incidence of progression may be attributed, in part, to the fact that they were retrospective reviews of patients referred for treatment. Thus, these studies tend to select larger and more progressive curves, while scoliosis in its earlier stages usually is not represented. Despite a number of studies, the natural history of idiopathic scoliosis and the risk of curve progression also remains obscure.

The incidence of spontaneous improvement (27.4%) observed in the present study is similar to that reported by Brooks (22%). Although the patients who demonstrated spontaneous improvement were similar in age to those who showed progression, they tended to have smaller curves when first screened. Unexpectedly, some children (9.5%) showed complete spontaneous resolution of the scoliotic curve, while >35% of the patients with left thoracic or left and right thoracolumbar curves showed a spontaneous decrease in the magnitude of their curve of at least 10°.

**CONCLUSION**

The factors found most important in their association with the natural history of the scoliotic curve were gender, curve pattern, and maturity. More specifically, the curve pattern was strongly indicative of the risk of progression when considered according to curve direction and sex of the child. The results of this study indicate girls with a right thoracic or double curve >10° and who have not reached menarche are at a high risk for progression. Boys with right lumbar curves also are prone to show curve progression. On the other hand, because of their low tendency to progress, left thoracic curves usually can be considered benign.

**REFERENCES**


