



Scoliosis in School-Aged Children

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Received 2018 March 18; Revised 2018 June 18; Accepted 2018 July 23.

Abstract

Context: Scoliosis is a frequent pathology in school aged children that may become a concern for parents and can challenge for practitioners and family doctors. The aim of the study is to make a comprehensive overview concerning scoliosis in school-aged children as well as elucidate red flags and related referral criteria for general practitioners that have to deal with school-aged children in their daily practice.

Evidence Acquisition: This article does not aim to be a systematic review as we have not applied a strict methodology. We conducted a bibliography search limited to MEDLINE and expanded with a search of the publications cited in the selected articles.

Results: The scoliosis research society (SRS) advise on annual examination of all children between the prepubertal period and 14 years of age. American academy of pediatrics (AAP), recommend a screening school children program between 10 to 16 years of age. These societies reported that school scans were necessary and useful for scoliosis, they emphasize on the benefits of receiving an early diagnosis and treatment of spinal deformities; thus, avoiding future surgical interventions.

Conclusions: Early diagnosis of scoliosis and assessment of the risk of curve progression is critical in school aged children. There is still a need for a large cohort study to ensure reliable consequences of school scoliosis screening programs.

Keywords: Scoliosis, Spine Deformity, School-Aged Children, School Screening

1. Context

Idiopathic scoliosis is a coronal plane deformity of the spine exceeding 10° with rotation of unknown etiology. A review of multiple studies reveal that idiopathic scoliosis tend to occur more often in girls with a prevalence of 0.4% - 2.22% versus 0.04% - 0.66% in boys (1, 2). Among children, idiopathic scoliosis is known to be more common in adolescents (10-16 years). Although the frequency of girls to boys is considered to be equal in curves under 10 degrees, the ratio in curves greater than 30 degrees tend to have a 10-fold increase in girls compared to boys. The prevalence decreases as the magnitude of the curve increases. Curves \geq 30 degrees is approximately 0.2%, the percentage decreases to 0.1% as the magnitude of the curve exceeds 40 degrees.

An important finding in a study conducted among 2000 patients examined for spinal abnormalities revealed that under the age of 21 years, scoliosis was the most frequent diagnosis (1439). Scheuermann's kyphosis (163) and spondylolisthesis (154) were the succeeding diagnosis (3).

1.1. Pathophysiology

Although several studies have investigated the pathophysiological process in idiopathic scoliosis, being up to date has not been able to precisely elucidate the underlying factors in its etiology. Etiology is unclear in more than 80% of cases. Rogala et al., reported 1231 cases of structural scoliosis, in which all cases except for 9 were idiopathic (4).

Although multiple genes influence the evolution, no specific gene has been identified to be responsible of the phenotypic expression. Studies conducted among twins have proven that genetics play an important role, however, it is not only a determinant. Subtle scoliosis can be observed throughout families with a wide range of clinical and radiological variations. Compared to the general population, there is a fifty-time greater risk a child will need treatment throughout his life if both parents have scoliosis (5). This concludes that there is a strong interaction between environmental factors and the genome in modulation that comes up with phenotypic variations. In the first decade, interaction with external environment triggers DNA methylation that leads to epigenetic effects.

1.2. Symptoms Associated with Scoliosis - Physical Examination

A vast majority of idiopathic scoliosis patients do not have particular symptoms related with the disease and are mostly pain free. In a multicenter study, 894 adolescent idiopathic scoliosis patients and 31 healthy controls were compared in terms of SRS-22 pain scores. The study revealed no significant difference between the scoliosis group and control group (6). A study carried out on 1743 men in the military (18 – 30 years), without additional spinal pathology, such as lytic or spondylolisthetic lesions, reported a 6.65% prevalence of idiopathic scoliosis. None of the participants experienced scoliosis related symptoms (7).

Among 310 AIS patients, although the prevalence of back pain was found to be moderately high only 1% was reported to have severe pain. A critical hallmark in the study is that none of the measured Cobb angles exceeded 20° (8). A study conducted among 30000 adolescents revealed that, compared to healthy controls, there is up to a 5 times risk of back pain in adolescents with scoliosis. Back pain was found to be significant in particular anatomical regions, especially in the middle right and upper regions of the back (9).

Research has proven that other various factors, such as social-economic status and ethnicity are important determinants over pain. Evaluated by SRS-30, Caucasians have been reported to have more pain compared to East Asians (10, 11). Clark et al., conducted a study on 3184 adolescents at the age of 15. Dual energy X-ray absorptiometry (DEXA) was used for screening. Clinical assessment including pain and function was made at the age of 18 years. They reported that spinal curves $\geq 6^\circ$ at the age 15 has further impact on back pain as the adolescent reaches maturity (12).

Although challenging data exists in the literature, the prevalence of back pain and scoliosis reveals that scoliosis cannot be the only underlying reason for lumbar back pain in a majority of adolescents complaining such symptoms. Apart from the diagnose of scoliosis, neurological and psychological status of the child should be evaluated. Interestingly, collected data also suggests a limited positive correlation between pain and Cobb angle (10, 13, 14).

A thorough history and physical examination is mandatory in order to elucidate spinal pathologies that can promote scoliosis. Detailed family history, menstruation, possible pain, and neurologic dysfunctions have to be questioned. Severe pain, neurologic symptoms, sudden rapid progression, direction of curves (left thoracic curves should arise suspicion since a vast majority of thoracic curves are right thoracic curves), and signs of

syndromes are red flags and should arise suspicion for secondary causes and require further evaluation with a multidisciplinary approach (15).

2. Screening

Diagnosis of scoliosis during the early period of life has the advantage of taking preventive measures, in particular cases treatment with conservative treatment methods only. Screening for idiopathic scoliosis is an important and feasible tool to reduce surgical interventions and related complications since bracing is found to be effective to prevent curve progression in most cases in the early stages (16).

Several methods are being used for screening: 1. Scoliometer (device used to measure the degree of rotation of the trunk), 2. Adam's forward-bending test, 3. Moire topography, 4. Measurement of rib hump.

Thulbourne et al. described the method to evaluate the contour and shape using humpograms (17). The angle of trunk rotation can be measured using a scoliometer. Moire topography is a biostereometric screening technique used to assess body surface asymmetry by projecting contour lines on a patient's back (18, 19) (Figure 1). In terms of comparing the accuracy of the above mentioned tests, Moire topography was found to be most sensitive with no false-negative results. The most widely used test, Adam's forward bending test, had a high percentage of false-negative results as well as low sensitivity (Figure 2). Compared to Adam's test, the negative predictive values of scoliometer and humpogram and their sensitivity was found to be superior (1, 20).

Apart from these, high-technology methods have been emerged for early and accurate detection of scoliosis in children. Ultrasound real-time linear array scanner, optoelectronic circumferential scanning, and digitization of the spinous processes have all been used with limited success. Despite the traditional methods and these new devices manufactured for screening purposes, there is still no consensus and standardization in school screening methods (21, 22).

In most of the developed countries, screening programs of adolescent idiopathic scoliosis in school age children were initiated. These programs led physicians to detect most of these scoliosis cases. Although there is consensus over the advantage of early detection of scoliosis, the efficacy of school scoliosis screening remains controversial (20, 23). Specific factors led to a significant decrease in such



Figure 1. Adam's forward bending test



Figure 2. Trunk rotation measurement by using a scoliometer

programs. Among these, excessive cost and over-referral is discussed to be the two major reasons (24, 25).

According to the U.S. preventive services, routine screening of asymptomatic adolescents for scoliosis is unnecessary. Despite this statement, The American academy of orthopedic surgeons and The American academy of pediatrics have recommended the screening of school age children during the adolescence period. Similarly, the orthopedic society of North America encourages early detection, thus, screening for scoliosis during adolescence (26, 27).

Another important concern about these programs are insufficient follow-up. Routine follow-up until sexual maturity, especially in moderate and high-risk patients, may lower the positive predictive value. It should be kept in mind that referred students, even with minor curves, may later progress needing invasive treatment modalities. In a cohort study, among the 2242 screened students, 68 students were evaluated with radiographs; PPV and sensitivity for detecting curves of 20 degrees were reported to be 17.4% and 64.0% (24).

3. Radiographic Evaluation and Additional Tests

Following abnormalities on physical examination and screening tests, radiographic evaluation is mandatory. Standard radiographic evaluation is a standing postero-anterior radiograph. Evaluation consists of measurement of the magnitude of the curve and maturity level of the child using the Risser staging, which is based on the level of fusion of iliac crest apophyses. Further imaging studies, such as magnetic resonance imaging (MRI), is needed when a left thoracic curve and uncommon neurologic findings such as sphincter dysfunction is detected (28).

4. Natural History - Prognosis

Factors that are known to be correlated with the progression of spinal curvature are skeletal immaturity, gender, and Cobb angle (15). Progression of the curve is strongly related with immaturity and magnitude of curve angle. Maturity can be evaluated by Risser classification

and Tanner stage. The Risser classification allows physicians to predict the potential of remaining skeletal growth. Maturity is graded from 0 to 5 depending on the level of bony ossification of the iliac crest apophysis starting from anterolateral to posteromedial. A study reported that there is significant negative correlation between risk of curve progression and Risser stage. The onset of the pubertal growth spurt followed by Tanner stage 2 and 3 has the maximum risk of scoliosis progression. Physicians should be aware of the risk during this time interval. In terms of gender, compared to males, risk of curve progression is 10-fold in females.

A Cobb angle over 25 degrees is one of the strong predictive factors for risk in curve progression. In addition to the above mentioned major factors, nonfunctional school furniture, inadequate sitting posture for prolonged time, overloaded backpacks, and inappropriate footwear should also be taken into account.

Table 1. Major Factors of Curve Progression (The Risk Scale)

Cobb Angle (Degree)	Potential Growing	Risser	Risk ^a
10 to 19	Limited	(2 to 4)	Low risk
10 to 19	High	(0 to 1)	Moderate
20 to 29	Limited	(2 to 4)	Low/moderate
20 to 29	High	(0 to 1)	High
> 29	Limited	(2 to 4)	High
> 29	High	(0 to 1)	Very high

^aLow risk = 5-15%; moderate risk = 15-40%; high risk = 40-70%; very high risk = 70-90%.

5. Treatment

Treatment options for patients with scoliosis are bracing, physical therapy, chiropractic care, biofeedback, electric stimulation, yoga, pilates, acupuncture, and foot orthosis. Among various methods; scoliosis specific exercises and bracing have been advocated to maintain a good balanced flexible spine with no back pain and adequate muscle strength. Only scoliosis specific exercises and bracing have been proven to have a significant impact. Compared to the group that received the unsupervised home exercise program, the group that received a total of 8-week program consisting of a weekly supervised spinal stabilization exercise revealed favorable results in terms of pain. Among these, bracing is the most commonly used option and has been proved to be beneficial and effective in controlling curve progression (29, 30). In a study conducted

by Nachemson et al., patients were evaluated in three different groups based on their treatment method. There was no significant difference between the electrical stimulation and observed groups, whereas treatment by brace had the highest success rate. A related study demonstrated that bracing had a high success rate (74%) at controlling curve progression (31, 32). The effectiveness of bracing on curve progression was supported by another study reporting that at skeletal maturity, 72% of patients that were braced had curves less than 50 degrees.

A cohort study reported that 72% of braced patients had curves $\leq 50^\circ$ at skeletal maturity, compared to 48% of corresponding patients who were not braced (33).

Based on the evidence provided from multiple studies, treatment with orthosis should be continued until Risser 4-5. It is mandatory to inform patients that bracing does not correct the curvature, however, it has a proven effect in controlling the progression of spinal curvature.

Current consensus for surgery is that it should be preferred in patients with remaining growth potential and Cobb angle ≥ 40 degrees. Although surgery alone is effective in the correction of the degree of spinal curves, there is insufficient data to prove that decrease in pain is correlated with the amount of correction achieved (34, 35).

The risk of surgery and the rate of neurologic injury have nowadays decreased impressively to 1/7000 procedures by using a spinal cord monitoring technology that consists of recording somatosensory and motor-evoked potentials.

6. Conclusions

There is still a need for a large cohort study to ensure reliable consequences of school scoliosis screening programs. Early diagnosis of scoliosis and assessment of the risk of curve progression is critical in school aged children. Although most patients with low risk criteria for curve progression and without any accompanying neuromuscular or genetic pathology can be observed until maturity, neglected curves that have high risk of progression with continued growth remaining are inevitable to undergo bracing and complex surgical procedures.

Table 2. Treatment of Adolescent Idiopathic Scoliosis

Curve Magnitude (Degree)	Risser	X-ray	Treatment	Refer
10 to 19	0 to 1	Every 6 months	Observe	No
10 to 19	2 to 4	Every 6 months	Observe	No
20 to 29	0 to 1	Every 6 months	Brace > 25 degrees	Refer
20 to 29	2 to 4	Every 6 months	Observe or brace	Refer
29 to 40	0 to 1	Refer	Brace	Refer
29 to 40	2 to 4	Refer	Brace	Refer
> 40	0 to 4	Refer	Surgery ^a	Refer

^aSurgery can be delayed if the patient is Risser grade 4.

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