Adolescent Idiopathic Scoliosis in Athletes: Is There a Connection?

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Abstract: The potential relationship between adolescent idiopathic scoliosis (AIS) and sports is rather vague. Sports have often been considered to be a causative factor of, or a treatment option for the former, particularly among adolescent athletes who are engaged in certain athletic activities. The highly repetitive nature of sports, amenorrhea, exercise-related exerted stress on the immature spine of professional adolescent athletes, and the joint laxity that may coexist during adolescence, have also been associated with an increased incidence of AIS. The purpose of this article is to discuss the potential connection between sports and AIS by reviewing the existing literature.

Keywords: adolescent idiopathic scoliosis; exercise; sports

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Introduction

Adolescent idiopathic scoliosis (AIS) is a structural, 3-dimensional rotational deformity of the spine manifested in otherwise healthy children at or around puberty.[1] The prevalence of AIS varies from 0.35% to 13%, depending on the threshold of the Cobb angle used, the age and sex of the enrolled patients (in mass-screening studies), and the regional and ethnic differences of the population evaluated.[2–5]

The actual cause(s) of AIS remain unclear.[6] The fact that AIS is often identified in several members of large families may suggest that its incidence is influenced by genetic factors, even though the genetic traits of patients with AIS are still very complex to comprehend clearly. Although several theories have been proposed, and many factors have been associated with the development of AIS, the exact pathogenetic mechanisms and all possible contributing factors that lead to its development are not fully understood.[7–13]

The possible connection between AIS and sports is rather vague. The latter has often been considered to be a causative factor of, or a treatment option for the former, especially among adolescent athletes who are engaged in certain athletic activities.[11–17] The highly repetitive nature of sports, amenorrhea, exercise-related exerted stress on the immature spine of professional or nonprofessional adolescent athletes, and the joint laxity that may coexist during adolescence, have also been associated with an increased incidence of AIS.[11,13–15] This article reviews the existing literature on potential connections between sports and AIS.

Materials and Methods

A literature search was conducted in MEDLINE from registry inception to March 2010 to identify all articles assessing the potential connection between the development of AIS and participation in sports. The keyword search term "scoliosis" revealed 14 570 articles, and the term "adolescent idiopathic scoliosis" narrowed the findings to 2817 articles. When combined with "etiology," the number of articles was narrowed to 867. When the terms "adolescent idiopathic scoliosis" and "sport" were combined, 40 articles were identified. The term "athlete" in our final search was not used as it appeared to eliminate relevant articles to just 2 (both written by us). A secondary bibliography search yielded no further articles. Because our aim was to evaluate the potential influence of athletic activities on the development of AIS, all articles evaluating the implementation of exercise in the treatment of patients with AIS were excluded from analysis. Of the 40 articles reviewed, 32 were excluded because they were not relevant with the topic of this review. Eight articles were finally deemed appropriate for this review (Table 1).

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Table 1. Analysis of All Available Published Studies Concerning the Cause-and-Effect Relationship Between Scoliosis and Sport Participation

Study	Study Type	Sport	Patients (N)	Control Group	Level of Evidence[a]	Evaluation	Reported Prevalence of Scoliosis	Comments
Becker[14]	Observational study	Swimming	336	No	Level IV case series	Clinical	6.9%	Based on clinical examination/no radiography used.
Warren et al[11]	Observational study	Ballet, dancing	75	No	Level IV case series	Clinical and radiological	24%	High percentage of a positive family history in athletes with scoliosis when compared with the healthy ones.
Hellström et al[12]	Comparative study	Soccer, tennis, gymnastics, wrestling	173	Yes	Level III-B case-control study	Radiological	2- to 3-fold increase in the prevalence of scoliosis among athletes when compared with nonathletes	Control group smaller and not matched/no physical examination used/rotation on radiography not considered.
Tanchev et al[15]	Comparative study	Rhythmic gymnastics	100	Yes	Level III-B case-control study	Clinical and radiological	12%	Control group not matched (2 groups comparable only concerning age).
McMaster et al[16,17]	Prospective study	Gymnastics, karate, skating, horse riding, dance classes, swimming	156	Yes	Level III-B case-control study	Clinical	Scoliosis was positively associated with the early introduction of patients to swimming and the ability to touch their toes, and negatively associated with participation in dancing, skating, gymnastics/karate, and horse riding activities	The increased ability of patients with scoliosis to touch their toes was attributed either to their physique or to the increased joint laxity.
Potoupnis et al[27]	Case report	Synchronized swimming	2	No	Level IV case series	Clinical and radiological	13.5-year-old female monozygotic twins, high-class athletes of synchronized swimming, discordant for AIS	Common genetic back-ground, exposure to the same environmental factor of synchronized swimming.
Kenanidis et al[6]	Comparative study	Swimming, volleyball, water polo, handball, basketball, cycling, gymnastics, tennis, soccer, running, rowing, boxing	2387	Yes	Level III-B Cross-sectional observational case-control study	Clinical and radiological	No statistically significant difference was found between athlete and non-athlete adoles-cents, athlete and non-athlete boys, and athlete and non-athlete girls, as far as the prevalence of AIS was concerned	Both groups were matched-comparable as far as age, weight, height, body mass index, prevalent extremity, onset of menstruation, and positive family history of scoliosis was concerned/definition of an athlete was given.
Meyer et al[28]	Comparative study	Aquatic sports athletics, dual sports, extreme sports, fighting sports, gymnastics, outdoor physical activity, team sports	169	Yes	Level III-B case-control study	Clinical and radiological	The study group was formed by girls with AIS	Physical and sporting activities were more common among ado-lescents with AIS and double major curves when compared with the control group.

[a]The level of evidence for each of the studies under review was provided by the authors of this study.
Abbreviation: AIS, adolescent idiopathic scoliosis.

Results

The prevalence of AIS has been reported to increase in leading athletes. In 1986, Becker[14] conducted a preliminary study to evaluate the incidence of scoliosis among a group of adolescents participating in competitive swimming programs. The screening procedure included observation of 336 of 1200 athletes in the standing erect and the forward-bending position, but not a radiographic evaluation, which can be considered a methodological flaw of the study. Adolescents participating in this study were elite athletes (ie, capable of swimming at an acceptable level before their evaluation). The male-to-female ratio was almost equal. The author reported a high prevalence of structural scoliosis (6.9%) in both the male and female groups. It is interesting to note that that the lateral curvature of all patients identified with scoliosis was related to the dominant side of the body in almost 100% of cases. Becker attributed the high prevalence of scoliosis to the coexisting muscular imbalance (often considered as a causative factor of scoliosis), which is developed by the repetitive swimming activity and the subsequent potential adaptation of vertebrae,[14] even though one might expect that swimming would not have that effect.

The development of scoliosis is often associated with dancing. Warren et al[11] identified 18 professional dancers out of a group of 75 to have AIS. The authors attributed this very high prevalence of scoliosis (24%) to the relatively delayed onset of menstruation and the high percentage of a positive family history in athletes with AIS when compared with the healthy ones. All patients were members of highly competitive professional ballet companies. The prevalence of scoliosis in dancers with delayed menarche was statistically significantly higher when compared with that of dancers without scoliosis who did not have amenorrhea. There was also a statistically significantly higher genetic predisposition for the development of scoliosis among members of the group of dancers with scoliosis when compared with the group of unaffected ballet dancers. Scoliosis was reported in 28% of the affected dancers' families, but only in 4% of those who were not affected. However, this finding does not reflect the complex genetics of scoliosis.

Hellström et al[12] radiographically evaluated the thoracolumbar spine of 117 male and 26 female athletes, and 30 nonathlete males who were used as a control group. Scoliosis was defined as a vertebral column curvature exceeding 10° in the anteroposterior view. The authors reported a 2- to 3-fold increase in the prevalence of AIS among athletes when compared with nonathletes. Scoliosis was significantly more common among male gymnasts than soccer players. The limitations of this study are that patients were not physically examined, the existence of vertebral rotation is not mentioned, and the relatively small and nonmatched control group could not allow for a true comparison between the 2 groups. On the other hand, physical examination is not as helpful as a radiograph, hence the results of this study are still interesting.

Tanchev et al[15] evaluated 100 Bulgarian female rhythmic gymnasts, with an age range between 10 and 16 years (mean, 12.44 ± 1.65 years), who had followed a training program for > 5 years. The prevalence of scoliosis was 12%. The scoliotic curves ranged from 10° to 30°. None of the participants had a family history of scoliosis or history of any disease or congenital abnormality resulting in secondary scoliosis. This prevalence of scoliosis was statistically significantly higher than the incidence of scoliosis among girls in the general population of Bulgaria (1.1%). The latter was determined following a mass screening program performed by the same team of physicians, who examined 4800 school children in Sofia, Bulgaria. This 10-fold increase in the incidence of AIS is certainly noteworthy. In contrast to previous similar reports, in which no etiologic implications were provided, Tanchev et al[15] reported a "dangerous triad" of factors of major importance that render the rhythmic gymnasts different in comparison with other children who are not practicing sports. According to the authors, these factors are: 1) generalized joint laxity acting as a hereditary predisposition; 2) delayed body growth and menarche due to physical, dietary, and psychological stress; and 3) persistent asymmetric overloading of the spine. The significantly higher incidence of scoliosis among rhythmic gymnasts and the specificity of this deformity led the authors to propose the introduction of a new clinical entity, which they termed "rhythmic gymnast scoliosis." One limitation of the study was that the 2 groups of patients were comparable only as far as the age of the participants, and the authors knew in advance whether the patients were athletes or not.

McMaster et al[16,17] assessed the physical activities of 79 patients with progressive AIS from 1 year of age to their early teens and compared them with those of a control group of 77 patients. The authors reported that progressive AIS was positively associated with the early introduction of patients to swimming and the ability to touch their toes, and was negatively associated with participation in dancing, skating, gymnastics/karate, and horse riding. Interestingly, this protective action of dancing appears to be in complete contradiction with the results reported by Warren et al.[11] McMaster et al[16,17] believe that the increased physical activities may possibly protect against AIS by involving neuromuscular feedback mechanisms common to all joints. They also note that the association of swimming early in life with the later development of AIS is rather vague and needs further research, while the increased ability of patients with AIS to touch their toes was attributed either to their physique[18–20] or increased joint laxity.[21] The latter is considered by many[22,23] as an important risk factor for the progression of scoliosis. However, it is unclear whether increased joint laxity is an independent risk factor for the development of scoliosis, or rather children with increased joint laxity are able to cope more easily with the demanding exercise program of a certain sport, hence they are more likely to continue practicing it successfully.

When investigating genetic and environmental etiologic factors influencing or predisposing to a certain disorder, such as AIS, twin studies have been of considerable value.[24,25] The incidence of monozygotic twins concordant for AIS has been reported to increase as high as 93%,[24] and this seems to be a strong evidence for the genetic origin of AIS. Kesling and Reinker[26] also supported that there is a statistically significant difference in the concordance between monozygotic and dizygotic twins. We recently reported the case of a pair of 13.5-year-old female monozygotic twins who were high-class athletes of synchronized swimming.[27] The twins were found to be discordant for AIS. Because the twins shared a common genetic background and were exposed to the same environmental factor of synchronized swimming (following an almost identical professional training schedule), one might have expected that they would show concordance for AIS. However, this was not the case, and this certainly questions the cause-and-effect relationship between AIS and exercising. Because AIS appears to be a multifactorial skeletal deformity, it seems that several factors (eg, genetics and environmental factors), acting together or independently, may be involved in its development.

We recently published a large cross-sectional observational study[6] comparing the prevalence of AIS among 2 statistically comparable groups of patients (athletes and nonathletes). Our aim was to determine whether athletic activities are related to the development of AIS. A curve of 10° (as defined by the Cobb method) combined with rotational deformity of the involved vertebrae was defined as AIS. In 99 cases (athletes: 48, nonathletes: 51), AIS was radiographically confirmed. No statistically significant difference was found between athlete and nonathlete adolescents ($P = 0.842$), athlete and nonathlete boys ($P = 0.757$), and athlete and nonathlete girls ($P = 0.705$), as far as the prevalence of AIS was concerned. The mean value of the Cobb angle of the main scoliotic curve was not statistically different between male athletes and nonathletes ($P = 0.45$) and female athletes and nonathletes ($P = 0.707$). We believe that these results most likely demonstrate that systematic practicing of a sport is not associated with the development of AIS, or appears to affect the degree of the main scoliotic curve. The latter finding is quite interesting because Meyer et al[28] reported that physical and sporting activities were more common among adolescents with AIS with double major curves when compared with a control group of patients. The difference between the groups was statistically significant ($P = 0.006$). The authors also reported that gymnastic activities were the most common sporting activity both in the study and the control group.

A factor that may influence the development of AIS in female athletes (particularly elite athletes) is amenorrhea. Prolonged hypoestrogenism is a well-recognized complication of weight loss, dieting, and physical training in girls and young women.[11,29] Estrogens have essential effects on the bone, which include stimulation of epiphyseal closure. The delayed growth and maturation cause a prolongation of the vulnerable years of growth, and this abnormality exposes the growth plates to the influence of mechanical factors (eg, pressure, impacts, microtrauma) for a longer period.[11,13,15,29] Because training for groups of female athletes (eg, ballet dancers, rhythmic gymnasts) begins at a young age, much of it takes place during adolescence, and because dieting to maintain low body weight is common, these athletes groups are most likely to have the effects of delayed sexual maturation on the growing skeleton, and require further study.

Discussion

After reviewing the available literature, we believe that it is not certain whether AIS and sports participation are related in a cause-and-effect model. Readers should be aware that it is even more difficult to reach secure conclusions regarding this controversial issue based on studies of low-level evidence that had many methodological differences and share little in common concerning the type of sports studied. Unfortunately, most relative reports in the literature are descriptive analyses of sport-specific cohorts. They lack comparison groups, blinded methodology, or statistical analysis. Furthermore, the patients' cohorts are usually relative small.

Another controversial issue is the definition of an athlete. Most studies provide very limited information regarding the athletic activities of the enrolled patients. Patients are often characterized as "elite." However, the years of practice, practicing schedule per week, and participation in sport clubs are rarely mentioned. It would be useful to universally apply standard criteria for the determination of an "athlete." Facing the same difficult dilemma in one of our recent publications,[6] we proposed the following definition of an "athlete," having in mind the potential influence of sport activities in the development of AIS: "A child that actively, continuously, and systematically practiced a sport for ≥ 2 years prior to his/her participation in a study is considered as an athlete. Furthermore he/she has to: follow a professional training schedule of at least 10 hours per week and be a member of an athletic association/club."

The exact definition of an athlete may influence to a great extent the prevalence of AIS among a group of adolescents. This is probably the reason why the prevalence of AIS may range from very low values[6] (that do not differ in a statistically significant manner when compared with those of a control group) to very high values.[11,15] Furthermore, the determination of the prevalence of AIS among patients who practice several different sports better evaluates the influence of athletic activities in general in the development of scoliosis.[6] On the other hand, sport-specific studies examining the prevalence of AIS among athletes practicing only 1 sport may clarify the pathogenetic mechanisms by which this specific sport influences the development of AIS.

Conclusion

The exact cause(s) of AIS remain unknown. Adolescent idiopathic scoliosis seems to be a multifactorial disease. It is certain that prospective, blinded, multicenter, randomized trials will be necessary in order to definitely determine whether AIS and sport activities are in any way related. Unfortunately, such a type of study is very hard to prepare, design, and perform. The universally accepted determination of who is and who is not an athlete will certainly remove several ambiguities and will help us reach secure conclusions.

The potential relationship between AIS and sports is rather vague. The latter has often been considered to be a causative factor of, or a treatment option for the former, especially among adolescent athletes who are engaged in certain athletic activities. Even though the exact definition of an athlete may greatly influence the prevalence of AIS among a group of adolescents, it seems that the prevalence of AIS may be high among athletes practicing certain sports (eg, gymnastics). On the other hand, the increased prevalence of AIS among athletes in general is not verified. Amenorrhea may play an important role in the development of AIS, mainly by allowing the immature female skeleton to be exposed to increased mechanical stress over a longer than normal period.

Conflict of Interest Statement

Eustathios I. Kenanidis, MD, Michael E. Potoupnis, MD, Kyriakos A. Papavasiliou, MD, Fares E. Sayegh, MD, and George A. Kapetanos, MD disclose no conflicts of interest.

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