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Scoliosis in Rhythmic Gymnasts

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Study Design. An anamnestic, clinical, radiographic study of 100 girls actively engaged in rhythmic gymnastics was performed in an attempt to explain the higher incidence and the specific features of scoliosis in rhythmic gymnastic trainees.

Objectives. To analyze the anthropometry, the regimen of motion and dieting, the specificity of training in rhythmic gymnastics, and the growth and maturing of the trainees, and to outline the characteristics of the scoliotic curves observed. An etiologic hypothesis for this specific subgroup of scoliosis is proposed.

Summary of Background Data. The etiology of scoliosis remains unknown in most cases despite extensive research. In the current classifications, no separate type of sports-associated scoliosis is suggested.

Methods. The examinations included anamnesis, weight and height measurements, growth and maturing data, eating regimen, general and back status, duration, intensity, and specific elements of rhythmic gymnastic training. Radiographs were taken in all the patients with suspected scoliosis. The results obtained were compared with the parameters of normal girls not involved in sports.

Results. A 10-fold higher incidence of scoliosis was found in rhythmic gymnastic trainees (12%) than in their normal coevals (1.1%). Delay in menarche and generalized joint laxity are common in rhythmic gymnastic trainees. The authors observed a significant physical loading with the persistently repeated asymmetric stress on the growing spine associated with the nature of rhythmic gymnastics. Some specific features of scoliosis related to rhythmic gymnastics were found also.

Conclusions. This study identified a separate scoliotic entity associated with rhythmic gymnastics. The results strongly suggest the important etiologic role of a "dangerous triad": generalized joint laxity, delayed maturity, and asymmetric spinal loading. [Key words: asymmetric spinal loading, delayed maturity, generalized joint laxity, rhythmic gymnastics, scoliosis, sport] **Spine 2000;25:1367–1372**

Despite extensive research, the etiology of idiopathic scoliosis remains unknown. Different theories have been discussed, but none of them has been definitely proved. Debates concerning the primary and the secondary changes in the deformed spine still continue, but to little avail. This helplessness is reflected in the accepted "multifactorial origin" of idiopathic scoliosis.

However, as the research advances, some "idiopathic" forms find their *primum movens* and may be classified elsewhere. Empiric observations gave impetus to important medical findings in the past, and could be useful now as well.

In Bulgaria, rhythmic gymnastics (RG) is a very popular sport among girls and young women. Almost every school has a training group. However, the most talented girls are trained in professional clubs according to special training programs (Figure 1). But this spectacular sport has turned out to create problems. As the only specialized department for spinal disorders in Bulgaria, the authors' institution offers the chance to observe a disquieting number of consecutive cases of scoliosis in girls engaged in RG for a longer period (5–10 years).

To date, no existing classifications of spinal deformities include a scoliotic category etiologically related to sports. There have been some rare reports on scoliosis associated with ballet[14] and some other sports such as tennis and javelin throwing,[8] but without etiologic implications.

The long-term observations of the current authors motivated them to plan and perform this study with purposes to establish the real incidence of scoliosis in RG trainees, to analyze its specific features, and to try suggesting some etiologic explanations for this specific scoliotic form.

Materials and Methods

This study included 100 girls ages 10 to 16 years (average, 12.44 ± 1.65 years) who had been trained in RG for more than 5 years. Primarily, 105 rhythmic gymnasts were evaluated, but for the purpose of selecting participants exposed only to effects from practicing RG, 2 girls with spina bifida occulta of L5 were excluded from this study, along with 1 girl with isthmic spondylolisthesis at L5–S1. The 3 of them had undergone previous radiograph examinations for low back problems. Also excluded were 2 who reported anamnestically that members of their families experienced some spinal disorders. As a result, 100 RG trainees were selected who had no familial anamnesis for spinal deformity and no past diseases or congenital abnormalities known to result in secondary scoliosis.

The evaluation included a history of familial and past diseases, weight and height measurements, growth and maturing (menarche), eating regimen (dieting, anorexic behavior), general and back physical examination, radiographic verification of all patients with suspected scoliosis, duration, intensity, and specific moments of the training process (*e.g.*, physical overloading, asymmetric loading of the spine).

The anthropometric, growth, and maturing data of the RG trainees were compared with the average data for Bulgarian girls of the same age group in nationwide statistical surveys.[2] The *t* test was used for statistical analysis.

Results

Physical examination of the back, including the forward bending test, revealed back asymmetry in 16 girls subjected to radiographic examination. Four of the girls who received

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Figure 1. Typical body habitus of a 16-year-old rhythmic gymnast. Exercise with a ball.

radiographs showed no structural scoliosis. Of the RG trainees, 12 had scoliotic curves of 10° or more (range, 10–30°), thus presenting a very high incidence of 12% (Figure 2). A significant difference was observed when this

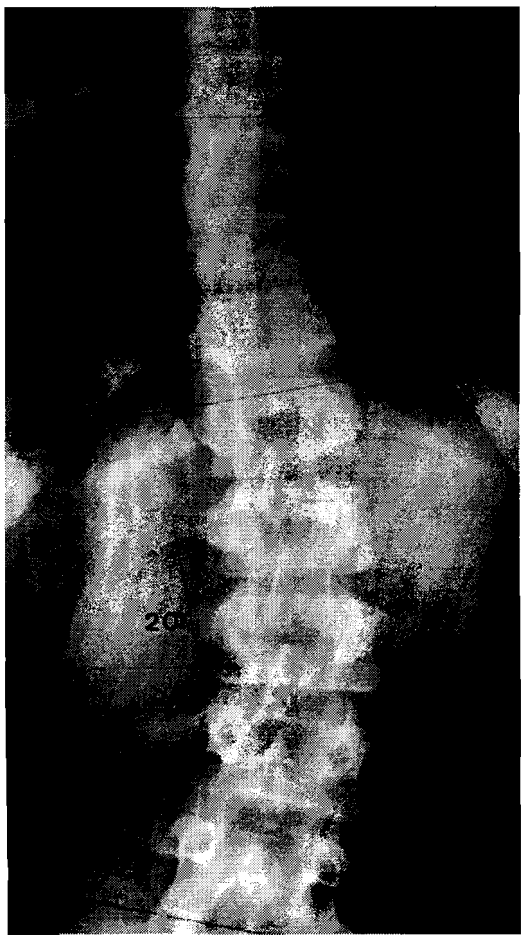

Figure 2. A lumbar scoliotic curve of 20° with right convexity in a 14-year-old girl who actively trained in rhythmic gymnastics for 6 years.

Table 1. Juxtaposition of Anthropometric, Growth, and Maturing Data in Rhythmic Gymnastics Trainees and Nontrainees

	Trainees	Nontrainees	*t* Test
Age (yr)	12.44 ± 1.65	13 ± 1.50	$P > 0.05$
Height (cm)	151.38 ± 9.66	155.3 ± 6.80	$P < 0.01$
Weight (kg)	36.32 ± 6.89	47 ± 9.40	$P < 0.001$
Right-handed (%)	99	82	$P < 0.05$
Joint laxity* (%)	100	5	$P < 0.001$
Menarche† (%)	10	90	$P < 0.001$

* Tests for generalized joint laxity according to Carter and Wilkinson.[1]
† Bulgarian girls have their menarche at the average age of 12.30 ± 1.26 years according to Damianova and Stanchev.[2]

percentage was compared with the percentage of scoliosis in normal girls of the same age group (1.1%), which was established by the same medical team in a screening program including 4800 school children in Sofia.[9]

The current screening results coincided with the data presented by Winter, who accepted the conclusion that the prevalence of scoliosis was rather constant worldwide (1% to 3%) for curves of 10° or more.[15] In what way do the RG trainees differ from their normal coevals, and how can the appearance of this endemic focus of scoliosis be explained? Table 1 presents the general data (anthropometry, growth, menarche) obtained in the current study as compared with the same data for nontrainees of the same average age.

Rhythmic gymnasts are very elegant, thin, and graceful. Their height and weight are significantly lower than those of nontrainees. The RG trainees manifest an obvious delay in the growth and maturing.

The training of the rhythmic gymnasts in this study started before adolescence, usually at the age of 5 years, and continued up to the moment of this study (an average of 6.63 ± 2 years). The most important criteria for the primary selection were flexibility and leanness. This can explain the 100% prevalence of generalized joint laxity in the participants. Everyday control of body weight was obviously compulsory, and probably the strict dieting (although not mentioned by the trainers and trainees), because of the absolute requirement of conformity to the thin image of an elite rhythmic gymnast. This is the reason why it is not surprising that the average body weight of the participants was found to be 10 kg lower than that of normal coevals. Dieting and physical training are known to delay menarche in girls who begin active sports or ballet at an early age.[13,14] This is typical for rhythmic gymnasts also.

Some specific traits in the training and exercising of rhythmic gymnasts were found. It was observed that all RG trainees have a flat back posture. This posture conforms to the elegance and outer appearance required for the girls practicing RG. It is maintained persistently in such activities as walking, standing, running, and jumping. The flat back posture is the constant body status of RG trainees, and the tendency to thoracic hypokyphosis and lumbar hypolordosis is evident (Figure 3).

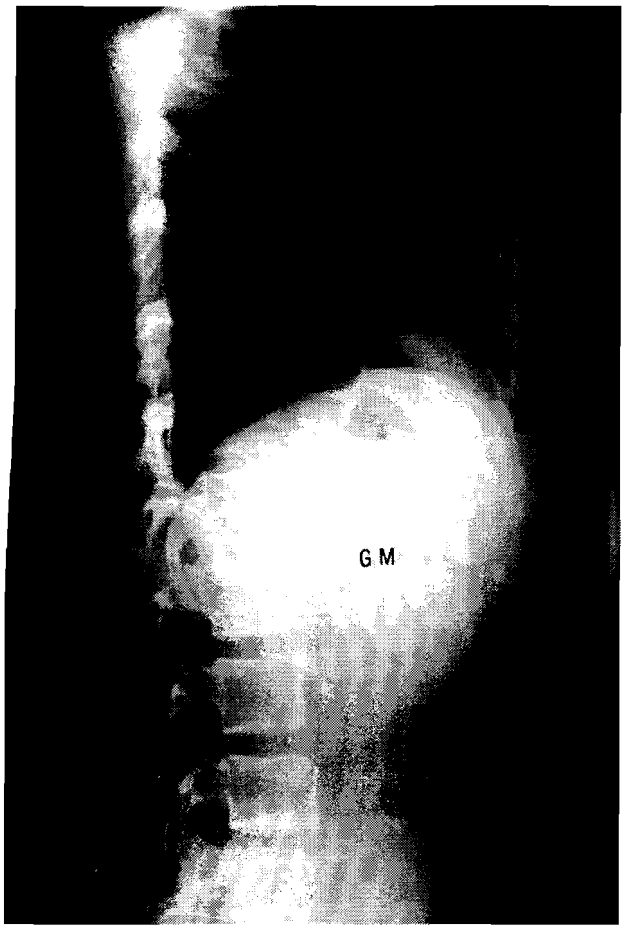

Figure 3. Lateral standing radiograph of a 12-year-old gymnast showing the typical flat back posture with a lack of any physiologic sagittal curvatures of the spine.

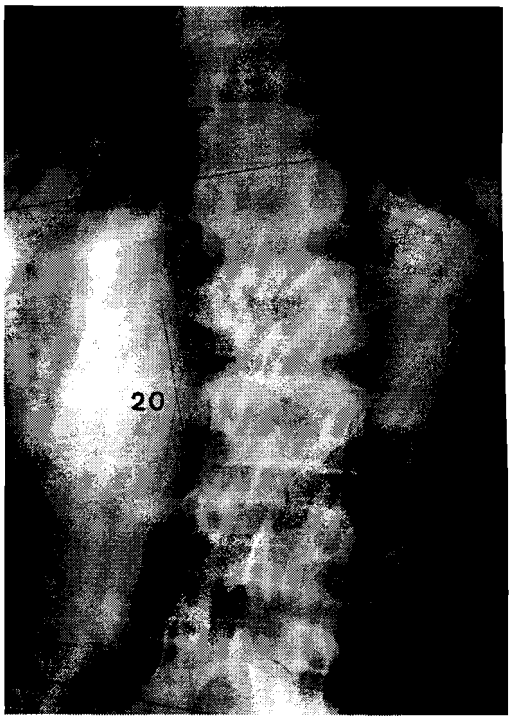

Figure 4. Enlargement of the anteroposterior radiograph of gymnast from Figure 2. In this figure, it is more easily seen that the structural changes in this very short curve engage only two vertebrae (L1 and L2) with a tendency to a degenerative molding (left edges of the upper endplates). These very mobile segments probably are impaired by the persistent asymmetric spinal loading in rhythmic gymnastics.

The intensity of training is extraordinarily high: 28.4 ± 12.16 hours a week. The training is carried out 6 days weekly, nearly 5 hours a day. This results in a significant overloading for juvenile and adolescent girls, considering that most girls begin active training in RG at the age of 5 years.

A very typical feature of RG is playing with different implements (hoop, ball, rope, ribbon, and clubs). Playing technique, figures, exercises, and the like were observed, directly during training and competitions or in videofilms. It was found that during approximately 75% of the playing time, the rhythmic gymnasts play with their "strong" hand to ensure better control in using the implements. This one-hand playing leads to an asymmetric loading of the spine, pelvis, and lower limbs. It was interesting to find that 99% of the rhythmic gymnasts in this study were right-handed, a prevalence significantly higher than in the normal population (82%).[2] No reasonable explanation could be found for this observation, but it could have some significance in defining the side of asymmetric spinal loading.

A very typical pose is one-leg standing when a rhythmic gymnast throws or catches the different implements, especially the ball and the ribbon. Some other typical figures and exercises observed give sufficient evidence for the conclusion that persistently repeated asymmetric axial loads are placed on the spine. For example, during the so-called "scales" or "balance" when the right arm is lifted upward in throwing, catching, or holding the ball or ribbon, the rhythmic gymnast jumps and lands on the right leg with the back in hyperlordosis, the pelvis is tilted to the right, and the lumbar spine is bent with convexity to the same side.

Also, some specific features of the scoliosis perceived in rhythmic gymnasts: flat back in 100% of the participants; mild curves (average Cobb angle, 16°; range, 10–30°); low curves engaging the most mobile segments of the spine (thoracolumbar in 58% and lumbar in 42% of the participants); no thoracic or double major curves; short curves (predominantly 4 to 6 segments or fewer); and prevalence of the right convexity (in 67% of the participants) over the left convexity (in 33% of the participants), which is uncommon for distal curve patterns (Figures 2 and 4).

■ Discussion

The pathogenesis of scoliosis seems to be well defined. Matzen[7] assumed that the *primum movens* for appearance of scoliosis can differ, but when the scoliotic curve

has once appeared, it develops according to its internal laws and "the scoliosis emancipates from its etiology." According to the widely accepted concept of biplanar asymmetry, the thoracic hypokyphosis and the lumbar hypolordosis may play an important role in the development of scoliotic deformities.[4,6] The current authors share this opinion of scoliotic pathogenesis entirely.

However, the etiology in most cases of idiopathic scoliosis remains unknown. In search of implications for the causes of idiopathic scoliosis, Harrington[5] postulated that "the growing scoliotic spine essentially represents structural living matter reacting to abnormal physical forces, resulting in an increasingly deformed state. Dysfunction of the growth process ultimately leads to malformation of the discretely articulated segmental spine."[p20] Harrington[5] assumed that multiple factors contribute to the etiology of idiopathic scoliosis. These factors considered to be of major importance are the mechanics of spine, nutrition, hormonal influence, and genetic tendency.

Concerning the mechanics of the spine, Harrington[5] referred to the Hueter-Volkmann principle, which claims that abnormal pressures placed on the facets and the vertebral bodies over a period of time affect the vertebral bodies, the facets, and the growth endochondral plates. Actually, Volkmann[11] developed the theory of bone and joint deformities caused by overloading of the growing skeleton, postulating that abnormal pressure hampers the growth of the epiphyseal plates in adolescents, whereas stretching stimulates it.

The current authors consider the hypothetical approach of Harrington very appropriate for explaining the appearance of scoliosis among rhythmic gymnasts. In their study, they found three factors of major importance that make the rhythmic gymnasts different from their coevals not involved in sports, and probably increasing very significantly the incidence of scoliosis among them: 1) generalized joint laxity as a hereditary terrain; 2) delayed growth and maturity caused by physical, dietary, and psychic stresses; and 3) persistent asymmetric overloading of the spine. These factors may contribute to the etiology of this scoliotic form. The authors called the coincidence of these three factors the "dangerous triad."

Carter and Wilkinson.[1] demonstrated persistent joint laxity to be an important predisposing factor in congenital dislocation of the hip. They reported also that generalized joint laxity affected both axial and limb joints. This statement suggests a possible relation to spinal disorders also. It is assumed that the increased range of motion in girls with generalized joint laxity could lead to increased pressure, impacts on the growth plates, or both, especially in girls with abnormal physical loading. In this way, the germinal or proliferative zones may be impaired and growth disturbed more or less substantially. This was suspected also in Harrington's[5] hypothesis, and this probably is the case in RG trainees.

Prolonged hypoestrogenism is a well-recognized complication of weight loss, dieting, and physical training in girls and young women. The delay in menarche is common in most girls who begin different sports at an early age.[13] Estrogen, in particular, has essential effects on the bone, which include stimulation of epiphyseal closure.[10] The delayed growth and maturing cause a prolongation of the "vulnerable growing years," a term introduced by Harrington,[5] and this abnormality exposes the growth plates to the influence of the unfavorable mechanical factors (pressure, impacts, microtrauma) for a longer period. This is what probably happens in the RG trainees, with 90% of them still having no menstruation at the average age when their normal coevals have had their menarche.

The persistent asymmetric overloading of the spine is typical for RG. It was very interesting to find that 99% of the participants were right-handed, which made them significantly different from their normal coevals, among whom 82% are right-handed.[2] The right-hand playing predetermines right-leg standing, jumping, taking off, and landing, with the body balanced by bending the thoracolumbar juncture and the lumbar spine with convexity, usually to the right.

The mechanics of one-leg standing, which leads to a temporary scoliotic posture with convexity to the ipsilateral side, has been well studied by Wagenhauser[12] and Debrunner and Hepp.[3] This specific mechanical situation repeats constantly in RG and probably produces overpressure in the most mobile segments of the spine (thoracolumbar juncture and lumbar spine), mainly affecting the left lateral and posterior parts of the growth endochondral plates (Figure 4). An important contributory effect could be ascribed to the flat spine of the RG trainees, which generally is recognized as a risk factor in the pathogenesis of structural scoliosis. An additional proof could be the presence of low and short thoracolumbar and lumbar curves in RG trainees. Most of them (67%) manifested convexity to the right. This curve pattern is the reverse of the usual idiopathic forms in this spine region, which predominantly manifest convexity to the left.

The absence of thoracic and double major curves in the participants also is noteworthy, giving some important evidence for the role of the thoracic cage as a buttress protecting their thoracic vertebrae, in particular their growth plates, from the impairing effect of the asymmetric spinal loading in RG. Although no definite consensus exists concerning the distribution of curve patterns in idiopathic scoliosis, it is generally accepted that the thoracic and double major curves occur the most frequently and the lumbar curves the least frequently. The current findings suggest the possibility of an asymmetrical hampering of the growth of the most mobile spinal segments in RG trainees.

There is a single published report on scoliosis associated with ballet dancing,[14] in which the prolonged hypoestrogenism and its effects on bone are thoroughly discussed. No implications for the etiologic relation between scoliosis and asymmetric loading of the spine are proposed. At this writing, no existing classification in-

cludes "sports scoliosis" or "sports-associated scoliosis" as a separate category, although it is not unusual to observe scoliotic deformities in adolescents and young people training for tennis, javelin throwing, or similar sports with asymmetrical loading of the spine.

The significantly higher incidence of scoliosis in rhythmic gymnasts and the specificity of this deformity suggest the exclusion of "rhythmic gymnasts' scoliosis" from the large group of idiopathic scoliosis. Therefore, the authors propose the separation of a sports-associated scoliosis, which may contribute to the better classification of this nosology. This specific scoliotic entity seems to have a phenotypic origin. The current study generates an etiologic hypothesis including the "dangerous triad" of generalized joint laxity, delayed maturity, and asymmetric overloading of the spine.

The authors believe that these risk factors may be the cause of primary scoliosis in some adolescents not involved in any sports, who usually are referred to as having idiopathic scoliosis. An appropriate extension of the research in this respect would be a comparative study juxtaposing the etiologic moments and the specificity of the deformity in rhythmic gymnasts to a control scoliotic group of girls with similar anthropometric, growth, and maturing data, but not engaged in sports.

References

1. Carter C, Wilkinson J. Persistent joint laxity and congenital dislocation of the hip. J Bone Joint Surg [Br] 1964;46:40–5.
2. Damianova M, Stanchev Z. Endokrinologia v detskata vazrast. Sofia: Medizina i Fiskultura, 1987:228–9.
3. Debrunner HU, Hepp WR. Orthopaedisches Diagnostikum. Stuttgart, New York: Georg Thieme, 1994:62–4.
4. Dickson RA, Lawton JO, Archer IA, et al. The pathogenesis of idiopathic scoliosis: Biplanar spinal asymmetry. J Bone Joint Surg [Br] 1984;66:8–15.
5. Harrington PR. The etiology of idiopathic scoliosis. Clin Orthop 1977;126: 17–25.
6. Leatherman KD, Dickson RA. The management of spinal deformities. London, Boston, Singapore, Sydney, Toronto, Wellington: Wright, 1988:44–54.
7. Matzen PF. Orthopaedie für Studierende. Leipzig: JA Barth, 1977:286–307.
8. Peterson L, Renström P. Sports injuries: Their prevention and treatment. Basle: Ciba Geigy, 1993:237–58.
9. Tanchev P, Dikov D, Dzherov A, et al. School screening for scoliosis in Sofia: An analysis of screening results of 4800 students. Orthop Trauma (Bul) 1996; 33:69–73.
10. Underwood LE, Van Wyk JJ. Hormones in normal and aberrant growth. In: Williams RH, ed. Textbook of Endocrinology. 6th ed. Philadelphia: WB Saunders, 1981:1149–91.
11. von Volkmann R. Chirurgische Erfahrungen über Knochenverbiegungen und Knochenwachstum. Virchows Arch Pathol Anat 1862;24:512–22.
12. Wagenhauser FJ. Das Problem der Haltung. Orthopäde 1973;2:128–39.
13. Warren MP. The effects of exercise on pubertal progression and reproductive function in girls. J Clin Endocrinol Metab 1980;51:1150–7.
14. Warren MP, Brooks-Gunn J, Hamilton LH, et al. Scoliosis and fractures in young ballet dancers. N Eng J Med 1986;314:1348–53.
15. Winter RB. Natural history of spinal deformity. In: Bradford DS, Lonstein JE, Moe JH, Ogilvie JW, Winter RB, eds. Moe's Textbook of Scoliosis and Other Spinal Deformities. 2nd ed. Philadelphia, London, Toronto, Sydney, Tokyo, Hong Kong: WB Saunders, 1987:89–95.

■ Key Points

- The authors found a 10-fold higher incidence of scoliosis in rhythmic gymnasts (12%) than in their normal coevals (1.1%).
- This study identified a separate scoliotic entity related to sports.
- The results suggest the important etiologic role of a "dangerous triad": generalized joint laxity, delayed maturity, and asymmetric spinal loading.

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Point of View

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The authors have published an interesting, stimulating, and provocative article. They report their observations of risk factors in adolescent female athletes involved in rhythmic gymnastics who develop scoliosis with specific features. The risk factors involve a "dangerous triad": generalized joint laxity, delayed maturity, and asymmetric spinal loading. The specific features for the type of "sports-associated scoliosis" that the authors describe include lumbar and thoracolumbar curves with no thoracic or double major curve patterns, and short curves with prevalence of convexity to the right. The authors put forth a strong argument for a category of so-called "sports scoliosis."

In their article, the authors have compared their results with the average data for Bulgarian girls of the same mean age from a previous nationwide statistical survey. Although this appears to be appropriate, I do not think it allows them to make such strong claims that prolonged asymmetric loading on the growth plates of the vertebral

bodies was a contributory factor, in and of itself, to the development of the specific type of scoliosis they describe in their article. To more completely prove this point or hypothesis, the authors would need to compare the rhythmic gymnastic trainees studied directly to a subgroup of right-handed nontrainees with joint laxity and delayed menarche from the previous nationwide survey they quoted. Generalized joint laxity with delayed menses and maturity can be common features for many young women, whether they are involved in sports or not, and especially if they are engaged in sports at an early age.

The authors stated at the end of the discussion section that more research is needed in this area. I believe that more studies are needed to help support the authors' eloquent arguments for a "dangerous triad" leading to "sports-associated scoliosis." Also, additional research is needed to answer the obvious question: Does such a specific scoliotic entity associated with sports exist for boys? The authors have made a significant contribution to our literature, but at the same time have created many questions. I encourage them to continue on with their excellent clinical research.