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Radiographic Abnormalities in the Thoracolumbar Spine of Young Elite Skiers

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ABSTRACT

An increased frequency of radiologic abnormalities in the thoracolumbar spine has been reported among young athletes in various sports, but there are no data concerning ski sports. To evaluate the incidence of these abnormalities in young elite skiers, we compared 120 skiers younger than 17 years old (alpine skiers, ski jumpers, and Nordic cross-country skiers) with a random sample of 39 control subjects of the same age who had no history of high-performance sports participation. Standardized anteroposterior and lateral radiographs of the entire lumbar spine, the lower thoracic spine, and the upper part of the sacrum were obtained from each athlete and each control subject. Radiographs were evaluated by two independent observers for the presence and size of anterior and posterior endplate lesions and Schmorl's nodes. The elite alpine skiers and ski jumpers demonstrated a significantly higher rate of anterior endplate lesions than did the control subjects. This finding might be attributable to excessive loading and repetitive trauma of the immature spine under high velocity, especially in the forward bent posture.

An increased frequency of radiologic abnormalities of the thoracolumbar spine has been reported among young athletes in various sports, such as soccer, gymnastics, water ski jumping, or wrestling, compared with nonathletes.[5,8,11,16,18,20,28–32] These abnormalities are often found in the anterior part of the vertebral ring apophysis of the lower thoracic and the upper lumbar spine,[2] and when they are accompanied by low back pain the condition is classified as "atypical" Scheuermann's disease.[9,10,31] Even though the fate of these abnormalities cannot be foreseen with certainty, the occurrence of degenerative disc disease and its sequelae has been assumed in several reports.[12,15,26,29]

Whereas the origins of typical Scheuermann's disease[22] have been a matter of controversy,[9,29] atypical Scheuermann's disease is considered to be strongly associated with trauma or excessive loading of the spine, especially in the flexed posture and during growth spurts.[5,27,29] Axial compression forces apparently cause vertebral endplate bulging, whereas compression of the immature spine in flexion is considered to cause anterior intravertebral disc herniation (marginal Schmorl's nodes).[8,9,23,24,27,29,30] Abnormalities of the vertebral ring apophysis are thought to be the result of failure in tension shear, analogous to the Osgood-Schlatter avulsion at the knee.[28]

We hypothesized that young elite alpine skiers and Nordic ski jumpers should have these radiologic abnormalities in the thoracolumbar spine to a greater extent than Nordic cross-country skiers and a random sample of nonathletically competitive adolescents in the same age group.

MATERIALS AND METHODS

The study group comprised young elite male and female athletes who were seen from June of 1994 through May of 1995 for a physical examination required for admission to a ski sports program. The control group consisted of patients of the same age who were admitted to the outpatient clinic of the University in Innsbruck and had a radiograph of the thoracolumbar spine. Exclusion criteria were a history of participation in a high-performance sport and evidence of fracture in the thoracolumbar spine.

Radiologic Protocol

Radiologic examinations were performed with the subject in the standing position by AP and lateral views. The film-to-focus distance was 100 cm, and a 20/40 film size was used (Fig. 1).

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Figure 1. Lateral radiograph showing anterior endplate lesions

Classification and Grouping of Endplate Irregularities

Radiographs were made anonymous by masking patient information and then coded and mixed in a random order before analysis to avoid any bias caused by expectation. On the lateral views, every lesion in each vertebra of the thoracolumbar and lumbar spine was assessed by two independent observers. The endplate was divided into three parts. Lesions in the posterior third were classified as "posterior lesions," and changes in the anterior two-thirds were classified as "anterior lesions" (involving the anterior vertebral edge) or "Schmorl's nodes" (not involving the anterior vertebral edge).

Quantitative Grading

To adjust for the individual vertebral size and magnification effects, the relative depth (or severity) of the lesion was calculated as a percentage of the vertebral body height (a ratio between the lesion's depth and the vertebral height, multiplied by 100). On the lateral views, the dorsal height was determined by drawing a horizontal line through the endplates and a vertical connecting line at the posterior vertebral border. The depth of each lesion was measured by connecting the horizontal line with the deepest point of the lesion. For all ratings, the average of the two raters' readings were considered the best estimate of the depth. If a lesion was found to be present by one rater and left out by the other a consensus value was determined for each discrepancy.

Statistical Analysis

Statistical analysis was performed using the SPSS program (SPSS, Inc., Chicago, Illinois). Besides descriptive statistics, various methods of variance analysis were applied. Frequencies were calculated in absolute and relative numbers, and mean values and ranges were assessed. Comparisons of athletes with control subjects were performed using the Mann-Whitney test. Subgroups were compared using the Kruskal-Wallis test and the Student-Newman-Keuls test. The chi-square test was used for comparison of nominal data such as sex. To estimate interobserver reliabilities, the single-measure intraclass correlation coefficient for two-way mixed effect model as well as interobserver bias using the procedure described by Bland and Altman[3] was calculated.

RESULTS

Subjects

A total of 120 elite athletes was included in the study: 78 boys and 42 girls (age range, 11 to 17 years; mean age, 14.6). These athletes performed ski sports (77 alpine skiing, 24 ski jumping, 19 country-cross skiing) and were examined by radiographic and orthopaedic evaluation. The average age at which the athletes started their sport was 6 years (range, 2 to 14), and the average age at which they started competitive sport was 8 years (range, 3 to 14). The control group consisted of 39 patients, 22 boys and 17 girls, with a mean age of 14.8 years (range, 14 to 16).

Fifty-six athletes and seven control subjects had lesions of the vertebral endplate (anterior or posterior endplate lesions and Schmorl's nodes). Almost 50% of the ski jumpers (N = 12) and alpine skiers (N = 37) had vertebral endplate lesions, in contrast to the control subjects with less than 20% (N = 7). Seven athletes who performed cross-country skiing were found to have lesions (36.8%).

Fequency of Endplate Lesions

The endplates for the T12, L1, L2, L3, L4, and L5 vertebral bodies were evaluated for lesions. Thus, with 12 endplates and 159 athletes and control subjects, a total of 1908 endplates were evaluated. Of these 1908, 12% (N = 229) had lesions. Altogether, including the upper and lower endplates, 181 anterior lesions, 37 Schmorl's nodes, and 11 posterior lesions were found. Descriptive statistics of anterior lesions, Schmorl's nodes, and posterior lesions with reference to sport are summarized in Table 1. Anterior endplate lesions occurred significantly more often in the group who performed competitive ski sport when compared with the control group ($P < 0.01$).

TABLE 1
Occurrence of Each Type of Lesion by Athletic Activity

Observations	Alpine skiing (*N* = 924)	Ski jumping (*N* = 288)	Cross-country skiing (*N* = 228)	Control (*N* = 468)	Total (*N* = 1908)
	N (%)	*N* (%)	*N* (%)	*N* (%)	*N* (%)
Anterior endplate lesions	107 (11.6)	47 (16.3)	21 (9.2)	6 (1.3)	181 (9.5)
Schmorl's nodes	16 (1.7)	9 (3.1)	5 (2.2)	7 (1.5)	37 (1.9)
Posterior endplate lesions	8 (0.9)	2 (0.7)	1 (0.4)	0 (0)	11 (0.6)

Interobserver Bias

There were no interobserver differences when considering location or type of the lesion. Interobserver bias when regarding relative depth of the lesion showed a mean difference of 1.4% (SD, ±3.5%). The single-measure intraclass correlation coefficient was 0.83.

Factors Related to Lesions

The occurrence of lesions was not related to age, sex, body mass index, age at start of sport, or start of competitive sport.

Severity of Lesion as Assessed by Number of Lesions per Examinee and Relative Depths

On average, the elite skiers had 3.9 endplate lesions per person (range, 1 to 8), compared with 1.9 lesions per person (range, 1 to 2) in the control subjects. Common mean relative depth of the lesions of both groups was 15.2% (range, 0% to 39.23%).

Distribution of Lesions with Reference to Vertebral Level

The distribution of lesions by vertebral level can be seen in Table 2. Anterior endplate lesions, as well as Schmorl's nodes, occurred more often in the upper lumbar spine and lower thoracic spine. The upper endplate was more often involved than the lower.

DISCUSSION

Fixed kyphosis of the thoracic spine together with radiographic changes according to Sorensen's radiographic criteria is commonly known as "classic" Scheuermann's disease.[8,9,25] Vertebral changes of the thoracolumbar and lumbar spine, such as anterior Schmorl's nodes and apophyseal ring abnormalities, with involvement of typically only one or two vertebral bodies when accompanied by mechanical-type back pain have been designated as "atypical" Scheuermann's disease by Greene et al.[9]

Although the origins of typical Scheuermann's kyphosis remain a matter of considerable controversy,[4,5,9,28,30] strenuous physical activity and trauma are considered to be strongly associated with atypical lumbar Scheuermann's disease.[1,27,28] This is reflected by recent reports about radiologic abnormalities in adolescent athletes such as wrestlers, soccer players, gymnasts, and waterski jumpers.[5,8,11,16,18,20,28–32] Our study clearly demonstrates that competitive alpine skiing and ski jumping and, to a lesser extent, cross-country skiing during childhood and adolescence are associated with the development of abnormalities of the thoracolumbar spine similar to atypical Scheuermann's disease.

As early as 1960, Roaf[21] demonstrated a central bulging of the vertebral endplate by vertical loading of the vertebrae. With increasing pressure, the endplate broke, leading to consecutive intravertebral discus herniation (Schmorl's nodes[23]) and discus height diminution resulting in disc degeneration.[28,29] The relationship between Schmorl's nodes and increased axial loading has been pointed out by Greene et al.[9] Bending forward greatly increases the intradiscal pressure,[13,19] causing fracture of the normal vertebral endplate (anterior Schmorl's nodes).[21,30] Using MRI, researchers have proven the presence of disc material in anterior Schmorl's nodes.[4,5,14,17,28,30] Therefore, Schmorl's nodes represent anterior disc herniations. Abnormalities of the vertebral ring apophysis, located outside the epiphyseal plates of the vertebrae, are considered to represent sequelea of an intravertebral disc herniation.[11] Hellström et al.[11] and Swärd et al.[28] have also discussed apophyseal traction through the longitudinal and intravertebral ligaments, analogous to the Osgood-Schlatter avulsion at the knee. Again, trauma and overload are suggested by several authors to be responsible for these vertebral changes.[11,16,19]

During competitive level alpine skiing and ski jumping, excessive loading of the spine occurs, especially when the skier bends forward. As a result, mainly anterior endplate lesions occur, especially in the upper lumbar spine, with involvement of four endplates per skier on the average. Because vulnerability of the spine in the growing athlete

TABLE 2
Number of Endplate Lesions with Reference to Vertebral Level

Vertebral level	Endplate	Anterior	Schmorl's nodes	Posterior
T12	Upper	17	0	5
	Lower	13	0	5
L1	Upper	28	0	6
	Lower	23	1	6
L2	Upper	34	3	10
	Lower	11	1	1
L3	Upper	24	2	3
	Lower	6	1	1
L4	Upper	16	1	0
	Lower	3	1	0
L5	Upper	6	0	0
	Lower	0	1	0

is high,[11,28,31] repetitive trauma and high-impact forces are most likely responsible for the changes seen, especially during growth spurts.

To be eligible for admission to the ski sport program in question all examined athletes had to prove to be tough competitors. Therefore, all of them had undergone vigorous training with differently skilled trainers since early childhood. Whether inappropriate training methods led to the vertebral changes found cannot be said. However, our findings provide strong evidence that intensive training and competition in ski sports during childhood and adolescence lead to a significantly higher number of anterior endplate lesions in the thoracolumbar and lumbar spine than should be expected in a normal population of the same age. This has to be attributed to a disproportion between applied load and loading capacity of the immature spine.

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