Anterior Limbus Vertebra and Intervertebral Disk Degeneration in Japanese Collegiate Gymnasts

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Background: Magnetic resonance imaging (MRI) studies have shown that gymnasts have a high prevalence of radiological abnormalities, such as intervertebral disk degeneration (IDD) and anterior limbus vertebra (ALV). These 2 abnormalities may coexist at the same spinal level. However, the relationship between IDD and ALV remains unclear.

Hypothesis: A significant relationship exists between IDD and ALV in Japanese collegiate gymnasts.

Study Design: Case-control study.

Methods: A total of 104 Japanese collegiate gymnasts (70 men and 34 women; age, 19.7 $\pm$ 1.0 years) with 11.8 $\pm$ 3.6 years of sporting experience participated. T1- and T2-weighted MRIs were used to evaluate ALV and IDD.

Results: The prevalence among the gymnasts of IDD and ALV was 40.4% (42/104) and 20.2% (21/104), respectively. The prevalence of IDD was significantly higher in gymnasts with ALV than those without ALV, as determined using the chi-square test. Logistic regression analysis demonstrated a significant association between IDD and ALV (adjusted odds ratio [OR], 6.60; 95% confidence interval [CI], 2.14-20.35). IDD was further grouped by whether it was present in the upper lumbar region (L1-2, L2-3, and L3-4 disks) or in the lower lumbar region (L4-5 and L5-S1 disks). Upper IDD had a greater association with ALV (adjusted OR, 33.17; 95% CI, 7.09-155.25) than did lower IDD (adjusted OR, 6.71; 95% CI, 1.57-28.73).

Conclusion: In Japanese collegiate gymnasts, ALV is a predictor of IDD, especially in the upper lumbar region.

Clinical Relevance: Information regarding ALV is important to prevent IDD in Japanese collegiate gymnasts.

Keywords: endplate lesion; gymnastics; intervertebral disk degeneration; magnetic resonance imaging

Male artistic gymnasts train and compete in 6 events: floor exercise, pommel horse, still rings, vault, parallel bars, and high bars. Female artistic gymnasts use 4 apparatuses: floor exercise, vault, balance beam, and uneven bars. These athletes participate in multiple events involving dynamic activity and unique body positioning unlike other sports.[21] Therefore, various types of sports injuries occur in these athletes. In one prospective study, common injury locations in elite and subelite gymnasts were reported to be the ankle, foot, and lower back.[18] Several studies report that the prevalence of low back pain (LBP) in gymnasts ranges from 49% to 85%.[20,34,35] Swärd et al[34] reported that the prevalence of LBP in gymnasts was 84.6% (22/26) for males and 65.4% (17/26) for females. Several risk factors for LBP have been documented; however, disorders of the lumbar spine may also be a risk factor for LBP in male and female gymnasts.

Several magnetic resonance imaging (MRI) studies have shown that gymnasts have a high prevalence of radiological abnormalities, such as intervertebral disk degeneration (IDD), anterior ring apophyseal injury (including the limbus vertebra), and Schmorl nodes.[6,13,33] Swärd et al[33] in particular investigated the prevalence of disk degeneration in 24 elite gymnasts and reported that 75% (18/24) had degenerated disks, which was significantly greater than the prevalence among controls. Furthermore, previous studies found that IDD was present in 46.6% (48/103) of athletes[19] and that IDD is a significant predictor for LBP in Japanese collegiate gymnasts (adjusted odds ratio [OR], 2.70; 95% confidence interval [CI], 1.10-6.66).[20]

Some risk factors contributing to IDD are age,[8] smoking,[5] obesity,[22] excessive physical loading,[12,26] decreased nutrition,[30] familial predisposition,[23] and genetic factors.[1,24,25] Despite the high prevalence of IDD in gymnasts, the risk factors remain unclear. There is an urgent need to

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One or more of the authors has declared the following potential conflict of interest or source of funding: This work was supported by JSPS KAKENHI (grant numbers 25870847 and 25350826).

The Orthopaedic Journal of Sports Medicine, 1(3), 2325967113500222
DOI: 10.1177/2325967113500222

clarify the risk factors of IDD in order to prevent LBP in gymnasts.[12] IDD usually occurs in the L5-S1 region in the general population.[7,12,16] In contrast, IDD frequently occurs in the L1-2 region in gymnasts[33]; however, its cause is poorly understood.

One MRI study found that the most common abnormality among 19 elite female gymnasts was anterior ring apophyseal injuries and moderate degenerative disk disease.[6] These 2 abnormalities, interestingly, may coexist at the same spinal level in 8 of 9 gymnasts (89%). A recent autopsy study showed that lumbar endplate lesions are associated with adjacent disk degeneration.[40] In fact, a recent study found that the most common MRI abnormalities in Japanese gymnasts were IDD and anterior limbus vertebra (ALV),[20] which is an endplate lesion. However, previous studies have predominantly focused on posterior limbus vertebra.[10,41] An ALV is believed to be asymptomatic, and it may be associated with IDD occurrence in gymnasts.

The present study aimed to examine the relationship between ALV and IDD in Japanese collegiate gymnasts. We hypothesized that a significant relationship would exist between ALV and IDD.

MATERIALS AND METHODS

Participants

Two gymnastics teams were recruited from the All Japan Student Gymnastics Federation. Participants included 104 Japanese collegiate gymnasts (70 men and 34 women; mean age, 19.7 $\pm$ 1.0 years) with 11.8 $\pm$ 3.6 years of sporting experience. Two participants had won medals (gold medals, n = 4) at the Olympics and World Championships. The 2 gymnastics teams regularly spent approximately 4 hours per day, 6 days per week in gymnastics training. This study excluded gymnasts who had previously undergone lumbar surgery.

The Ethical Committee for the Nippon Sport Science University approved the present study protocol. All gymnasts provided written, informed consent before participation. Information regarding the purpose of the study, potential risks, and protection of the rights of the participants was provided to all gymnasts. This was a case-control study with a cohort of collegiate gymnasts. We intended to investigate the predictors of IDD.

Physical Characteristics and Years of Sporting Experience

The physical characteristics of the gymnasts (ie, height and weight) were determined, and information on age, years of sporting experience, and injury histories were obtained using questionnaires.

Magnetic Resonance Imaging Procedures

Magnetic resonance imaging (MRI) scans (AIRIS II, Hitachi, Japan) were performed using a 0.3-T unit that used surface coils with a body coil in the supine position. The following sequences were used:

1. A T1-weighted fast spin echo (FSE) sequence in the midsagittal plane, including (at least) L1 to S1, with a repetition time (TR) of 400 ms and an echo time (TE) of 25 ms.
2. A T2-weighted FSE sequence in the midsagittal plane, including (at least) L1 to S1, with a TR of 3000 ms and a TE of 125 ms.

Image interpretation was performed to evaluate 2 MRI abnormalities: ALV and IDD. An ALV was defined as a separate, sclerotic, and triangular ossicle that was adjacent to, but separate from, the vertebral endplate. The affected endplate contains an adjacent, irregular, focal, sclerotic defect that is secondary to chronic herniation of disk material through the attachment of the annulus fibrosus (Figure 1).[15,26] The gymnasts were divided into 2 groups: (1) ALV and (2) no ALV. IDD was defined as reduced signal intensity of the intervertebral disks from L1-2 to L5-S1. The grading system for the assessment of IDD was based on the Pfirrmann classification[28] in which grades 3, 4, and 5 indicate degeneration (Figure 1).[12,16,25] We also grouped IDD by whether it occurred in the upper (L1-2, L2-3, and L3-4 disks) or lower (L4-5 and L5-S1 disks) lumbar regions. Because an orthopaedic spine specialist often makes a diagnosis based on images, the MRI scans from each gymnast were examined by 2 orthopaedic surgeons specializing in spine disorders. Both orthopaedic surgeons were blinded to the injury histories of the gymnasts. If there were any discrepancies, consensus was reached before final grading.

Statistical Analysis

The prevalences of ALV and IDD were compared between the 2 groups using the chi-square test. To investigate the relationship between ALV and IDD, logistic regression analyses were performed with adjustments for sex and weight. An overwhelming number of studies have reported that height does not affect IDD, whereas weight does. Therefore, we adjusted our analyses for weight. Furthermore, the relationship between ALV and IDD in the upper and lower lumbar regions was evaluated using logistic regression analyses with adjustments for sex and weight. The relationship between IDD and ALV in the cranial and caudal endplates was also examined by logistic regression analyses with adjustments for sex and weight. Peduzzi et al[27] suggested that 30 case samples were required for logistic regression analysis (3 explanatory variables). A P value <.05 was considered statistically significant. All statistical analyses were performed by using IBM SPSS Statistics 18 software for Windows (IBM, Armonk, New York, USA).

RESULTS

Prevalence of ALV

The prevalence of $\geq$1 ALV in gymnasts was 20.2% (21/104). We assigned the gymnasts to either the ALV group (n = 21)

Figure 1. Intervertebral disk degeneration and adjacent anterior limbus vertebra. A magnetic resonance imaging scan of the intervertebral disk of a gymnast with grade 3 intervertebral disk degeneration at L4-5 (black arrow). An adjacent anterior limbus vertebra is also present in the upper endplate of L5 (white arrow).

or the no ALV group (n = 83). Of the 1040 endplates (from the L1 caudal endplate to the S1 cranial endplate) that were examined, ALV was present on 3.8% (20/520) of the cranial endplates and 1.2% (6/520) of the caudal endplates.

Prevalence of IDD

The prevalence of ≥1 IDD in gymnasts was 40.4% (42/104). Additionally, we evaluated 520 lumbar intervertebral disks (L1-S1) and found that 10.6% (55/520) were degenerated. With regard to the spinal level of the lesion, IDD was present in 5.1% (16/312) of upper disks (L1-L4) and 18.8% (39/208) of lower disks (L4-S1).

Effect of Sporting Experience on MRI Abnormalities

The presence of ALV was associated with years of sporting experience (crude OR, 1.25; 95% CI, 1.05-1.50; $P < .05$). The presence of ALV was also associated with years of sporting experience (adjusted OR, 1.28; 95% CI, 1.05-1.56), after adjusting for sex and weight by logistic regression analyses. Conversely, the presence of IDD was not associated with years of sporting experience (OR, 0.93; 95% CI, 0.83-1.04; $P = .191$).

TABLE 1
Relationship Between ALV and IDD[a]

	IDD			
	Yes (n = 42)	No (n = 62)	χ^2	*P* Value
ALV	15	6	10.53	<.01
No ALV	27	56	—	—

[a]ALV, anterior limbus vertebra; IDD, intervertebral disk degeneration.

TABLE 2
Logistic Regression Analysis of Gymnasts With IDD[a]

	Crude		Adjusted		
Group	OR	95% CI	OR	95% CI	*P* Value
Sex	1.05	0.46-2.42	2.11	0.66-6.71	.208
Weight	1.04	0.98-1.09	1.07	0.99-1.15	.086
ALV	6.33	2.09-19.24	6.60	2.14-20.35	<.001

[a]IDD, intervertebral disk degeneration; ALV, anterior limbus vertebra; OR, odds ratio; CI, confidence interval.

Relationship Between ALV and IDD

The locations of ALV and IDD were at the same spinal level in 19 of 26 adjacent ALV. Table 1 shows the prevalence of IDD in gymnasts with and without ALV. The prevalence of IDD was significantly greater in gymnasts with ALV than in those without, as determined by the chi-square test.

Logistic Regression for Predicting IDD

Logistic regression analysis indicated a significant association between IDD and ALV (adjusted OR, 6.60; 95% CI, 2.14-20.35) (Table 2). Upper IDD was significantly associated with ALV (adjusted OR, 33.17; 95% CI, 7.09-155.25) (Table 3). Lower IDD similarly was significantly associated with ALV (adjusted OR, 6.71; 95% CI, 1.57-28.73) (Table 3).

We further examined the association between the location of ALV (20 cranial and 6 caudal) and IDD. The presence of IDD was significantly associated with cranial ALV (adjusted OR, 15.45; 95% CI, 3.75-63.68) but not with caudal ALV (adjusted OR, 2.96; 95% CI, 0.51-17.24).

DISCUSSION

The main finding of this study was that ALV is significantly associated with IDD in collegiate gymnasts.

TABLE 3
Logistic Regression Analysis of Gymnasts With Upper and Lower IDD[a]

	Crude		Adjusted		
Group	OR	95% CI	OR	95% CI	*P* Value
Upper IDD					
Sex	1.66	0.53-5.24	3.70	0.58-23.48	.166
Weight	1.02	0.94-1.10	1.10	0.98-1.23	.124
ALV	28.7	6.67-123.2	33.17	7.09-155.25	<.001
Lower IDD					
Sex	0.74	0.30-1.83	1.69	0.50-5.69	.398
Weight	1.06	0.99-1.12	1.08	0.99-1.17	.060
ALV	6.44	1.55-26.85	6.71	1.57-28.73	<.01

[a]IDD, intervertebral disk degeneration; ALV, anterior limbus vertebra; OR, odds ratio; CI, confidence interval.

Endplate lesions are reportedly a significant risk factor, but a direct relationship between ALV and IDD was not established.

In this study, a high prevalence of ALV and IDD in collegiate gymnasts was shown. This has been reported previously.[20] We also found that ALV, but not IDD, was positively associated with years of sporting experience. On the other hand, age and years of sporting experience have little effect on IDD in gymnasts. Rachbauer et al[29] suggest that ski sports during childhood and adolescence lead to a significantly greater number of anterior endplate lesions in the spine. Baranto et al[3] also reported in their 15-year follow-up MRI study that the frequency of apophyseal changes did not increase over time, which suggests that these changes occur at a younger age and remain stable in adults. Therefore, we suggest that ALV likely occurs during childhood. On the other hand, Tertti et al[37] found that only 3 of 35 competitive gymnasts (aged 8-19 years) had disk degeneration. In fact, our study found a significant association between years of sporting experience and ALV but not IDD. Considering these results, we believe that ALV occurs earlier than IDD in gymnasts.

Our main finding indicated a positive association between ALV and IDD. As reported previously, ALV may occur at a young age. Hence, ALV may be a predictor of IDD. Young athletes with ALV have a high risk of developing IDD. We also performed a logistic regression test and found that ALV was significantly associated with IDD, concomitant with confounding factors. Because the mature intervertebral disk is largely avascular, diffusion from blood vessels of the annulus and the vertebral endplate form the source of nutrition.[38] The relationship between IDD and endplate injury has been investigated through various approaches in animal studies,[2,9] cadaveric studies,[40] and MRI studies.[30,31] On the basis of their autopsy study, Wang et al[40] recently suggested that the disruption of endplate integrity may trigger a series of pathological cascades that eventually result in adjacent IDD. Moreover, Kerttula et al[17] suggested that endplate injury is strongly associated with IDD in young patients with a previous wedge-shaped compression fracture. Hsu et al[14] found that in the younger patients, high lumbar disk lesions were associated with pathologies such as endplate defects, Scheuermann disease, limbus vertebra, previous fractures, retrolisthesis, or segmental instability. Previous research has examined the relationship between IDD and injury of the anterior part of the ring apophysis in elite female gymnasts.[6] However, these studies had several deficiencies, including using relatively small sample sizes and not taking confounding factors into account. In this study, more than 100 athletes, including Olympians, were included. By using logistic regression tests, we also examined the effect of ALV with regard to confounding factors. Based on these findings, we conclude that ALV is a significant predictor of IDD in gymnasts.

In the present study, we found that ALV of the upper (L1-4) and lower (L4-S1) lumbar regions was a significant predictor of IDD. We also found that the OR for IDD was greater in the upper lumbar region than in the lower lumbar region. Upper IDD might be more affected by ALV than lower IDD. Several researchers have found that IDD in the lower lumbar region is common among a similarly aged population.[36] Athletes show the same tendency.[7,39] Swärd et al[33] found that IDD at the L1-2 level was common among gymnasts. With regard to upper IDD, ALV-induced malnutrition states may be a trigger for tissue damage. These results collectively suggest that adjacent ALVs play a crucial role in initiating upper IDD in gymnasts.

Intervertebral disk degeneration was associated with cranial, but not caudal, ALV. A possible reason is that caudal ALV has a low prevalence. Previous research has found that the most common vertebral ring apophysis injury among athletes (including gymnasts) occurred at the anterior cranial part of the ring apophysis.[32] Therefore, we believe that IDD associated with cranial ALV is significantly different from that in the lumbar regions.

The mechanism of ALV formation in gymnasts is unclear. Several authors have proposed that ALV results from the intrabody herniation of disk material.[11,13] Other authors have suggested that traction through the attached soft tissue (eg, the anterior longitudinal ligament and diaphragmatic muscle) causes injury to the anterior part of the vertebral ring apophysis.[13,32] As discussed previously, a high prevalence of IDD in the upper lumbar region is characteristic for gymnasts. Battié et al[4] reported that familial aggregation, which includes heredity, accounted for 54% of IDD in upper lumbar levels and 32% of IDD in lower lumbar levels. We recently found that Japanese gymnasts with the TT genotype of the COL11A1 polymorphism have an increased risk of having limbus vertebra.[19] We also discussed previously that ALV may precede IDD. Thus, we suspect that young athletes with the COL11A1 TT genotype develop ALV more easily, and this may lead to IDD.

A limitation of the present study was that it did not consider other factors (ie, gene polymorphism, year of practice, starting age of practice, biomechanical factors, and the strengths and interactions) to clarify the relationship between ALV and IDD in collegiate gymnasts.

CONCLUSION

The results of this study suggest that ALV is associated with IDD and is a significant predictor of the development of IDD in Japanese collegiate gymnasts. We believe that additional studies using a longitudinal design and other factors are needed to establish the association between IDD and ALV.

ACKNOWLEDGMENT

The authors thank Shigeki Nishida for the technical assistance and Yukio Takeda for assistance with participant administration.

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