

Effects of Competition Level on the Prevalence and Incidence of Lumbar Disk Degeneration in Japanese Collegiate Gymnasts

Koji Koyama,^{*†} PhD, Koichi Nakazato,[‡] PhD, Yoshiaki Kubo,[†] PhD, Koji Gushiken,[§], Yoshiaki Hatakeda,[§] MS, Kyoko Seo,[§] PhD, Takuya Nakase,[§] MS, and Kenji Hiranuma,^{||} MD, PhD

Investigation performed at Nippon Sport Science University, Tokyo, Japan

Background: Lumbar disk degeneration (LDD) occurs frequently in athletes. Researchers have found that LDD occurs mainly in the lower disks (L4/L5 and L5/S1) in the general and athletic populations. However, a retrospective study showed a high prevalence of LDD in the upper lumbar disks (L1/L2), especially in elite gymnasts.

Purpose: To investigate the effect of competition level on the prevalence and incidence of LDD in the upper lumbar disks (L1/L2).

Study Design: Cross-sectional study; Level of evidence, 3; and cohort study; Level of evidence, 2.

Methods: We conducted 2 studies to evaluate the effect of competition level on the prevalence and incidence of LDD in Japanese collegiate gymnasts. In study 1, a cross-sectional study of 298 collegiate gymnasts was conducted between 2011 and 2015. Competition levels were categorized as regional, national, and international, and T2-weighted magnetic resonance imaging (MRI) was used to evaluate LDD. Chi-square testing was applied to assess differences in the prevalence of LDD and spinal levels among the 3 competition levels. In study 2—a prospective cohort study—LDD progression and its related risk factors were investigated in 51 collegiate gymnasts. Baseline lumbar MRI scans and measurements of physical function (generalized joint laxity and finger-floor distance test) were performed in March 2014. Follow-up lumbar MRI scans were obtained 2 years later, in February 2016. Logistic regression analyses were performed to investigate the relationship between competition level and LDD progression.

Results: In study 1, the prevalence of at least 1 degenerated disk in the regional, national, and international groups was 44.2% (19/43), 44.7% (98/219), and 52.8% (19/36), respectively ($P = .655$). The prevalence of LDD at L1/L2 in the international group was significantly higher than that in the other 2 groups ($P = .018$). In study 2, the presence of LDD at L1/L2 was associated significantly with international-level competition (adjusted odds ratio, 47.8; 95% CI, 2.75-830.50).

Conclusion: In Japanese collegiate gymnasts, competing at the international level was found to be a risk factor for LDD at L1/L2.

Keywords: gymnastics; intervertebral disk degeneration; magnetic resonance imaging; risk factor

Lumbar disk degeneration (LDD) occurs frequently in athletes. Recently, Abdalkader et al¹ found that elite athletes have a high prevalence of LDD, as detected using magnetic resonance imaging (MRI) in athletes in the 2016 Rio de Janeiro Summer Olympics games. Many studies have previously reported the presence of an association between LDD and low back pain (LBP) in athletes.^{8,14} Therefore, there is a need to clarify the risk factors for LDD to prevent LBP in elite athletes.

Several researchers have found that LDD occurs mainly in the lower lumbar disks (L4/L5 and L5/S1) in elite athletes.^{1,4,8,15} In contrast, Swärd et al²¹ found that LDD at the

L1/L2 level was common among elite male gymnasts. Moreover, a recent study found that elite swimmers had more LDD in the upper lumbar disks (L1/L2) but tended to have less LDD in the lower lumbar disks.⁶ Although the location of LDD reflects the characteristics of a particular sport, the cause of LDD in the upper lumbar disks in elite athletes remains unclear.

As described above, a previous study by Swärd et al²¹ found a high prevalence of LDD in the upper lumbar disks (L1/L2) in elite gymnasts. However, this study had a small sample size and cross-sectional design. In contrast, Koyama et al¹³ found that LDD occurred in both the upper (L1/L2, L2/L3, and L3/L4) and the lower (L4/L5 and L5/S1) disks in collegiate gymnasts. However, this study included both international- and regional-level gymnasts. Therefore, competition level may play a role in the occurrence of LDD.

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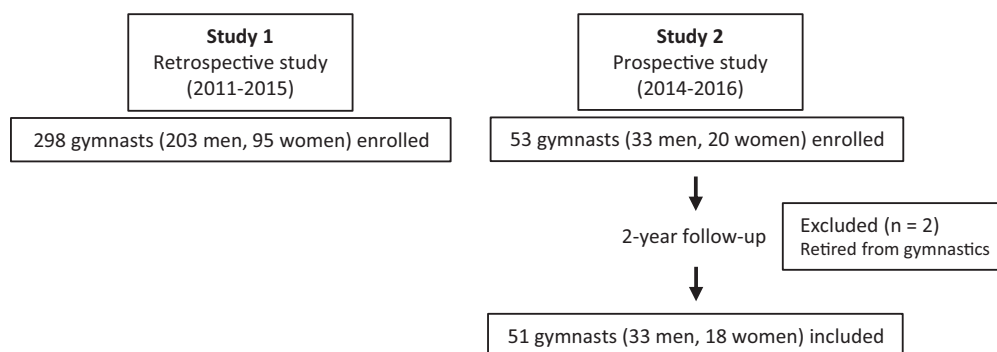


Figure 1. Flow diagram of studies 1 and 2.

To clarify whether competition level directly relates to the prevalence of LDD at L1/L2 in gymnasts, it is necessary to conduct a prospective study.

This study aimed to investigate the effect of competition level on the prevalence and incidence of LDD in the upper lumbar disks (L1/L2). We hypothesized that the prevalence of LDD at L1/L2 would be significantly higher in international-level gymnasts and that the competition level of gymnasts would be a risk factor for LDD at L1/L2.

METHODS

We conducted 2 studies to determine the prevalence of LDD at different competition levels (study 1) and to investigate the progression and risk factors (including competition level) related to LDD (study 2) in Japanese collegiate gymnasts. Study 1—a cross-sectional study—was conducted between 2011 and 2015; study 2—a prospective cohort study with a 2-year follow-up—was conducted between March 2014 and February 2016. The study protocol was approved by the ethics committee of our institution, and 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.

Participants

Study 1. The All-Japan Student Gymnastics Federation comprises 65 teams (about 1100 gymnasts). Two gymnastics teams were recruited. The participants were 298 Japanese collegiate gymnasts (203 men and 95 women; mean age, 20.0 ± 1.1 years; mean gymnastics experience,

13.0 ± 3.7 years). These teams trained regularly, 4 hours per day for 6 days per week. Gymnasts who had previously undergone lumbar surgery were excluded.

Study 2. We recruited 1 gymnastics team from the All-Japan Student Gymnastics Federation. A total of 53 gymnasts (33 men and 20 women) who regularly trained 4 hours per day for 6 days per week participated in the baseline evaluation. Among these gymnasts, 2 did not participate in the follow-up study because they had retired from gymnastics. Figure 1 shows the participant enrollment for both studies.

In both studies, the gymnasts were divided into 3 groups based on performance at the regional, national, or international level, according to the competition levels previously described by Kikuchi et al.¹⁰ Gymnasts at the international level had participated in world championships, including the Olympic Games, or had placed first in Japanese national championships.

Patient Characteristics

In both studies, the characteristics of the gymnasts (age, height, weight, body mass index) were determined. Information on years of gymnastics experience was obtained from questionnaires. Moreover, all gymnasts were asked about their current experience with LBP (yes or no) and were asked to score their LBP on a 10-point visual analog scale, in which a score of at least 5 was considered to indicate the presence of LBP.¹⁸

MRI Procedures

In both studies, MRI scans (AIRIS II; Hitachi) were performed using a 0.3-T unit that used surface coils with a

*Address correspondence to Koji Koyama, PhD, Department of Judotherapy, Tokyo Ariake University of Medical and Health Sciences, 2-9 -1 Ariake Koto-ku, 135-0063 Tokyo, Japan (email: koyama@tau.ac.jp).

[†]Department of Judotherapy, Tokyo Ariake University of Medical and Health Sciences, Tokyo, Japan.

[‡]Department of Exercise Physiology, Graduate School of Health and Sport Sciences, Nippon Sport Science University, Tokyo, Japan.

[§]Sports Methodology (Gymnastic), Nippon Sport Science University, Tokyo, Japan.

^{||}Graduate School of Health and Sport Science, Nippon Sport Science University, Tokyo, Japan.

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Ethical approval for this study was obtained from Nippon Sport Science University (ref No. 009-G003).

body coil in the supine position. The imaging protocol consisted of a T2-weighted fast spin-echo sequence in the midsagittal plane, including (at least) L1 to S1, with a repetition time of 3000 ms and an echo time of 125 ms.

LDD was defined as the reduced signal intensity of the intervertebral disks from L1/L2 to L5/S1. The grading system for the degree of LDD was based on the Pfirrmann classification,¹⁹ in which grades 1 and 2 indicate normal disks and grades 3, 4, and 5 indicate degeneration.^{8,9,13,14} Because an orthopaedic spinal specialist often makes a diagnosis based on images, the MRI scans from each gymnast were examined by 2 experienced orthopaedic surgeons (K.H. and M.T.) specializing in spine disorders. Both orthopaedic surgeons were blinded to the descriptive and clinical data of the gymnasts. If there were any discrepancies between the orthopaedic surgeons, they were discussed before the final grading. The kappa score for interobserver agreement of the Pfirrmann disk degeneration grading was 0.918, indicating strong agreement.

Study 2: Baseline Evaluation

The initial evaluation included descriptive parameters and assessment of LDD using MRI for a prospective study. Baseline data were collected for physical function measurements, such as generalized joint laxity (GJL) and finger-floor distance (FFD).

Study 2: Physical Function Measurements

GJL is known to be related closely to orthopaedic injuries and disease.^{3,16,17,20} The criterion used most widely for detecting GJL is the Beighton score, which requires the performance of 5 maneuvers for a total of 9 points (4 bilateral and 1 unilateral).² The Beighton score measurements were as follows: (1) passive dorsiflexion of the little fingers $>90^\circ$; (2) passive apposition of the thumb to the flexor aspect of the forearm; (3) hyperextension of the elbows $>10^\circ$; (4) hyperextension of the knees $>10^\circ$; and (5) forward flexion of the trunk, with the knees straight, so that the palms of the hands rest easily on the floor.

The FFD is used to assess the mobility of the spine in the overall motion of bending forward. From an upright standing position on a table with a height of 40 cm, participants were asked to reach for the tabletop with maximum forward bending and full extension of the knee joint. The FFD was measured from the fingertips to the tabletop. If the fingertips extended below the level of the table, the FFD was recorded as a negative value.

All participants underwent physical function measurements (GJL and FFD tests) at baseline. Each examination was performed by the same examiner (K.K.).

Study 2: Endpoint Assessments at 2-Year Follow-up

The degree of LDD in the participants was determined using the modified Pfirrmann classification.²² Grades 1 and 2 were classified as normal disks and scored as 0. For each

higher degree of LDD, the score increased by 1 point. A sum score (range, 0-15) of LDD for the 5 lumbar disks was obtained by adding each lumbar disk score.

Statistical Analysis

In both studies, characteristics and physical function of the gymnasts were analyzed using 1-way analysis of variance, post hoc least significant difference test, chi-square test, and Fisher exact probability test for multigroup comparison. The chi-square test was used to assess differences in the prevalence of LDD and spinal level among the regional, national, and international level groups. In addition, in study 1, the relationship between LDD and LBP was assessed using the chi-square test.

In study 2, to investigate the relationship between competition level and LDD progression, logistic regression analyses were performed after adjusting for sex, weight, and years of gymnastics experience. These independent variables were chosen because variables with $P < .05$ were retained in each model and previous studies have reported that sex and weight affect LDD. Although there was a significant difference in height for the 1-way analysis, there was a high correlation between height and weight via Pearson correlation coefficient ($r > 0.8$). To avoid multicollinearity weight was used for the analysis. Hence, weight was used for the analysis. For all comparisons, a P value of $<.05$ was considered statistically significant. All statistical analyses were performed using IBM SPSS Statistics 23.0 software for Windows (SPSS IBM).

RESULTS

Patient Characteristics (Study 1)

The characteristics of the 298 gymnasts in study 1 are summarized in Table 1. There were 43 gymnasts in the regional group, 219 in the national group, and 36 in the international group. According to univariate analysis, the international group was significantly associated with shorter height ($P < .01$), lower weight ($P < .05$), and more years of experience ($P < .01$) compared with the regional group. However, no significant differences in height, weight, or experience were observed between the international and national groups ($P = .31, .06, \text{ and } .18$, respectively).

Prevalence of LDD (Study 1)

In study 1, the prevalence of LDD in the regional, national, and international groups was 44.2% (19/43), 44.7% (98/219), and 52.8% (19/36), respectively ($P = .655$). The prevalence of LDD was not associated with the competition level. In addition, we evaluated 1490 lumbar intervertebral disks (L1-S1) and found that 13.4% (199/1490) disks were degenerated. Comparison of the prevalence of LDD at each spinal level among the 3 groups revealed that L1/L2 was degenerated significantly more frequently in the international group ($P = .018$) (Table 2).

TABLE 1
Characteristics of Study 1 Participants (n = 298)^a

Variable	Regional (n = 43)	National (n = 219)	International (n = 36)	P
Sex, male:female, n	32:11	148:39	23:13	.136
Age, y	19.9 ± 1.1	20.0 ± 1.1	20.1 ± 1.1	.817
Height, cm	165.1 ± 8.0	161.5 ± 7.3 ^b	159.3 ± 8.2 ^c	<.01
Weight, kg	59.4 ± 7.6	57.0 ± 7.6	54.4 ± 7.6 ^b	<.05
BMI	21.7 ± 1.5	21.8 ± 1.5	21.4 ± 1.6	.319
Experience, y	8.1 ± 4.1	13.7 ± 3.0 ^c	14.4 ± 3.2 ^c	<.01
Low back pain, n (%)	2 (4.7)	33 (15.0)	6 (16.7)	.167

^aData are reported as mean ± SD unless otherwise indicated. BMI, body mass index.

^bSignificantly different from regional group ($P < .05$).

^cSignificantly different from regional group ($P < .01$).

TABLE 2
Prevalence of LDD at Each Lumbar Vertebral Level in Study 1^a

Disk Level	Regional (n = 43)	National (n = 219)	International (n = 36)	P
L1/L2	1 (2.3)	12 (5.5)	6 (16.7)	.018 ^b
L2/L3	1 (2.3)	14 (6.4)	5 (13.9)	.115
L3/L4	2 (4.7)	20 (9.1)	6 (16.7)	.183
L4/L5	7 (16.3)	50 (22.8)	6 (16.7)	.492
L5/S1	13 (30.2)	50 (22.8)	6 (16.7)	.354

^aValues are presented as n (%). LDD, lumbar disk degeneration.

^bSignificant difference among the 3 groups ($P < .05$).

TABLE 3
Relationship Between LDD and LBP in Study 1^a

	LDD		χ^2	P
	Yes (n = 136)	No (n = 162)		
LBP	22	19	1.233	.267
No LBP	114	143	-	-

^aLBP, low back pain; LDD, lumbar disk degeneration. Dashes indicate not available.

Relationship Between LDD and LBP (Study 1)

The prevalence of LBP in the gymnasts of study 1 was 13.8% (41/298). Table 3 shows the prevalence of LDD in the gymnasts with and without LBP. The prevalence of LDD was not associated with LBP, as determined using the chi-square test.

Patient Characteristics (Study 2)

In study 2, the mean age of the 51 participants was 19.3 ± 0.8 years, and the mean gymnastics experience was 13.1 ± 3.3 years. There were 7 gymnasts in the regional group, 37 in the national group, and 7 in the international group. At baseline, height was significantly shorter in the international group than in the regional group ($P < .05$), and the years of experience in the international and national groups were significantly more than those of the regional group ($P < .05$ for both groups). However, there were no significant differences in the GJL or FFD among the 3 groups (Table 4).

Changes During the 2-Year Interval

At baseline MRI evaluation, 23 of the 51 gymnasts in study 2 (45.1%) had 1 or more degenerated disks. At the

TABLE 4
Characteristics and Physical Function at Baseline in Study 2 Participants (n = 51)^a

Variable	Regional (n = 7)	National (n = 37)	International (n = 7)	P
Age, y	19.6 ± 1.4	19.3 ± 0.6	19.4 ± 0.8	.605
Height, cm	167.4 ± 8.5	160.6 ± 7.6	156.5 ± 9.7 ^b	<.05
Weight, kg	60.6 ± 10.8	56.7 ± 8.2	53.3 ± 8.1	.291
BMI	21.5 ± 2.1	21.8 ± 1.5	21.6 ± 1.6	.816
Experience, y	9.4 ± 5.4	13.4 ± 2.5 ^c	15.6 ± 1.6 ^c	<.01
Beighton score, point	1.7 ± 1.3	2.5 ± 1.5	1.9 ± 1.9	.293
FFD, cm	-20.3 ± 3.9	-23.4 ± 4.9	-25.6 ± 6.1	.144

^aData are reported as mean ± SD unless otherwise indicated. BMI, body mass index; FFD, finger-floor distance.

^bSignificantly different from regional group ($P < .05$).

^cSignificantly different from regional group ($P < .01$).

TABLE 5
Degree of LDD at Baseline and Follow-up in Study 2^a

Disk Level	Regional (n = 7)		National (n = 37)		International (n = 7)	
	Baseline	Follow-up	Baseline	Follow-up	Baseline	Follow-up
L1/L2	0	0	1	4	2	6
L2/L3	0	0	3	4	1	2
L3/L4	0	0	7	7	2	2
L4/L5	1	2	11	10	0	0
L5/S1	1	1	12	12	1	1

^aValues are presented as modified Pfirrmann score (range, 0-15), where grades 1 and 2 (normal) = 0 points, grade 3 = 1 point, grade 4 = 2 points, and grade 5 = 3 points. LDD, lumbar disk degeneration.

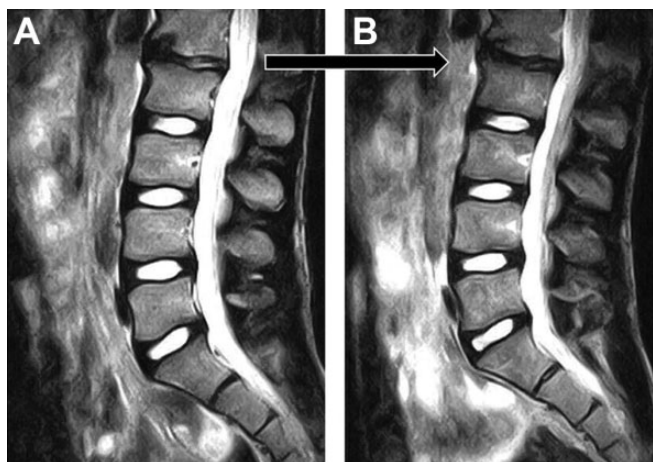


Figure 2. Progression of LDD at L1/L2 on sagittal T2-weighted MRI scans in gymnasts competing at the international level. (A) At baseline. (B) Two-year follow-up MRI scan showing a reduction in signal intensity of the intervertebral disk at L1/L2 (black arrow). LDD, lumbar disk degeneration; MRI, magnetic resonance imaging.

2-year follow-up MRI evaluation, 24 gymnasts (47.1%) had 1 or more degenerated disks. Table 5 shows the degree of LDD at each spinal level according to modified Pfirrmann score at baseline and follow-up. For the international group, the degree of LDD was highest at L1/L2 (Figure 2).

Logistic Regression for Predicting LDD occurrence

Using logistic regression analysis of study 2 data, we further examined the significant risk factors along with confounding factors. The presence of LDD at L1/L2 was significantly associated with competition level (adjusted odds ratio [OR], 47.8; 95% CI, 2.75-830.50; $P = .008$) (Table 6). Although competition level was a risk factor for LDD progression of the entire lumbar spine according to the crude OR (10.4; 95% CI, 1.78-60.6), there was no significant association according to the adjusted OR (6.58; 95% CI, 0.93-46.6; $P = .059$) (Table 7).

DISCUSSION

These cross-sectional and prospective studies investigated the effects of competition level on the prevalence and incidence of LDD in Japanese collegiate gymnasts. In the cross-sectional study (study 1), the prevalence of 1 or more degenerated disks was not associated with the level of competition. However, the prevalence of LDD at L1/L2 in the international group was significantly higher than that in the other 2 groups. In the prospective study (study 2), the presence of LDD at L1/L2 was associated significantly with international-level competition.

Prevalence of LDD in International-Level Gymnasts

The main finding of this study was that the prevalence of LDD at L1/L2 was significantly higher in the international group. We also found that the international competition level for gymnasts was a risk factor for LDD at L1/L2. In general, LDD, particularly in the lower lumbar disks (L4/L5 and L5/S1), is commonly reported in the general population.^{5,23} Similarly, the prevalence of LDD at each spinal level for 6 competitive sports was reported by Hangai et al,⁸ who observed LDD predominantly in the lower lumbar disks. With regard to competition level, Kaneoka et al⁹ found that the comparison of the prevalence of LDD between elite and recreational swimmers revealed that L5/S1 was degenerated significantly more frequently in elite swimmers. In gymnastics, a previous study found that LDD at the L1/L2 level was common among 24 male elite gymnasts.²¹ Our study indicated that the prevalence of LDD in the lower lumbar disks was common among regional and national athletes. Therefore, we believe that gymnasts competing at the international level have a high frequency of L1/L2 LDD. In other words, we think that these morphological changes of the upper lumbar disk were sport-specific injuries of elite gymnasts.

Effects of Competition Level

In the present study, the presence of 1 or more degenerated disks was not associated with level of competition. These findings are somewhat in contrast to the results of Goldstein et al,⁷ who found excessive LDD among Olympic-level gymnasts. One previous study on LDD in elite swimmers

TABLE 6
Logistic Regression Analysis for Predicting LDD at L1/L2^a

Variable	Crude OR (95% CI)	Adjusted OR (95% CI)	P
Sex	0.33 (0.40-3.06)	0.06 (0.00-4.14)	.189
Weight	1.01 (0.91-1.11)	0.95 (0.76-1.19)	.638
Gymnastics experience	1.22 (0.85-1.76)	0.98 (0.69-1.40)	.930
Competition level	28.0 (3.56-220.2)	47.8 (2.75-830.50)	.008 ^b

^aLDD, lumbar disk degeneration; OR, odds ratio.

^bSignificantly associated with presence of LDD at L1/L2 ($P < .01$).

TABLE 7
Logistic Regression Analysis for Predicting LDD^a

Variable	Crude OR (95% CI)	Adjusted OR (95% CI)	P
Sex	0.90 (0.20-4.13)	0.42 (0.02-7.74)	.561
Weight	0.98 (0.90-1.07)	0.96 (0.81-1.13)	.623
Gymnastics experience	1.33 (0.94-1.87)	1.19 (0.84-1.67)	.322
Competition level	10.4 (1.78-60.6)	6.58 (0.93-46.6)	.059

^aLDD, lumbar disk degeneration; OR, odds ratio.

showed that lumbar disks in elite (high-load) swimmers were injured more frequently than were those in recreational (low-load) swimmers.⁹ In general, there was an association between level of competition and the presence of 1 or more degenerated disks. On the contrary, in gymnastics, an epidemiology study found that subelite female gymnasts experienced more injuries to the lower back than did elite female gymnasts (19.4% and 9.2%, respectively).¹² In gymnastics, every 4 years, concurrently with the Olympic games, there are rule changes, and the skill level continues to evolve. As a result, even for regional group gymnasts, skills such as the Yurchenko vault, the Tkatchev, the uneven and horizontal bars, somersaults, and twists are difficult. Although there are no data on the loading of the lumbar disks during gymnastics skills, these skills require repetitive extension, flexion, and torsion motions of the spine. Therefore, we think that the level of competition has little effect on the prevalence of LDD in modern gymnasts.

GJL and the FFD

Several studies have reported that individuals with GJL are at an increased risk for musculoskeletal injury.^{3,16,17,20} With regard to LDD, increased GJL has been associated closely with a lower prevalence of LDD in patients (age, 30-40 years), and the increased lumbar lordosis associated with GJL might explain the decreased risk of LDD demonstrated by Kim et al.¹¹ However, we could not obtain sagittal spinal alignment on lateral radiographs in this study. The reason why GJL was not a risk factor for LDD collegiate gymnasts is unknown. Thus, further investigation is needed to clarify the relationship between GJL and LDD. Similarly, FFD was not a risk factor for LDD in collegiate gymnasts. We considered that gymnasts perform specific actions such as hyperflexion and hyperextension of the

spine, resulting in physical loading of the lumbar disks. Although a previous study indicated that a combination of repetitive flexion and extension increases the risk of injury to the spinal disks in animals,²⁴ LDD may occur during the growth spurt in gymnasts. Thus, we do not believe that FFD is a risk factor for LDD in collegiate gymnasts.

Limitations

Several limitations of this study should be acknowledged. First, it was not possible to consider other factors (ie, gene polymorphism, biomechanical factors, and muscle strength) to clarify the risk factors for LDD in Japanese collegiate gymnasts, although these are known to contribute to LDD. This limitation may have led to false-positive findings. We believe that additional studies to evaluate other factors are needed to establish the association between competition level and LDD progression. Second, the sample size was not large enough to reach a definitive conclusion in a prospective study. It was challenging to find 1 gymnastics team with many levels of competitive collegiate gymnasts with a relatively long history of gymnastics experience. Therefore, further studies with a larger sample population are required to confirm these findings. Finally, intraobserver agreement could not be assessed. MRI findings were evaluated by 2 experienced orthopaedic surgeons in our study. As the evaluators were medical doctors specializing in spinal disorders, we believe that their evaluation was highly reliable.

CONCLUSION

Although the prevalence of 1 or more degenerated disks was not associated with the level of competition, the prevalence and incidence of LDD was significantly higher at the L1/L2 disks in international Japanese gymnasts. The

results of this study indicated that competition level is a risk factor for LDD at L1/L2 in Japanese collegiate gymnasts.

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