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Etiology and nature of intervertebral disc degeneration and its correlation with low back pain

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Abstract Low back pain (LBP) is a common musculoskeletal disorder that affects the general and athletic populations. Intervertebral disc degeneration (IDD) is one of the causes of LBP and a current topic in the orthopedic and sports medicine fields. The correlation between IDD and LBP seems controversial. In Part I of this review article, we examine the etiology and nature of intervertebral disc degeneration in terms of classification and definitions of lumbar IDD, prevalence of lumbar IDD, and possible risk factors for lumbar IDD. In Part II, we compare IDD and LBP in general and athletic populations.

Keywords : lumbar IDD, low back pain (LBP), magnetic resonance imaging, sports, athlete

Introduction

According to the literature, the lifetime prevalence of low back pain (LBP) is reportedly 70-85%¹⁾. LBP is known as a major source of disability and substantial contributor to health care costs²). In Japan, the medical costs of work-related LBP have increased in recent years, creating an economic burden on Japanese society³⁾. In athletic populations, several studies have reported that the prevalence of LBP was 49-85%^{4,5)}. In 142 top Swedish athletes (participating in wrestling, soccer, tennis, and gymnastics), the prevalence of LBP was 84.6% (22/26) for male gymnasts and 65.4% (17/26) for female gymnasts⁴⁾. LBP is a common musculoskeletal disorder affecting the general and athletic populations⁶⁻⁸⁾. Schmidt et al.⁹⁾ recently reported that LBP is a common symptom of adolescent athletes who play competitive sports. Accordingly, LBP is a common musculoskeletal disorder in both adults and adolescents. We believe that LBP is a major problem that requires preventive measures. However, the exact morphologic cause of LBP remains unclear for most patients.

In clinical practice, LBP is divided into specific and nonspecific types. Nonspecific LBP, the most common type, features pain of undetermined origin. The source of LBP generally includes the muscle (strain), ligament (myofascial sprain and strain), nerve (radiculopathy), joint (facet and sacroiliac joint), bone (pars interarticularis defect), and intervertebral disc (herniation and degeneration)¹⁰⁾. In particular, intervertebral disc degeneration (IDD) is a current topic in the orthopedic and sports medicine fields because several studies have suggested that IDD is a major source of LBP^{11,12)}. The LBP caused by IDD is called discogenic pain. However, IDD is commonly asymptomatic¹³⁻¹⁸⁾, and the correlation between IDD and LBP remains unclear.

Given this background, in Part I of this article, we focus on the classification, definition, prevalence, and risk factors of lumbar IDD, while in Part II, we review the correlations between lumbar IDD and LBP.

Part I. Etiology and nature of intervertebral disc degeneration

Classification and definitions of lumbar IDD. IDD is usually diagnosed by T2-weighted magnetic resonance imaging (MRI) as a decline in signal intensity. Several researchers have reported IDD classification systems based on sagittal T2-weighted images such as Schneiderman's classification¹⁹⁾ (Table 1), Pfirrmann's classification²⁰⁾ (Table 2), and modified Pfirrmann's classification²¹⁾. The observers (i.e., radiologist, orthopedic surgeon) are blinded to the patients' clinical status in the general evaluation. Schneiderman's classification uses a scoring method to facilitate comparisons among individuals, and the total score is calculated by the summation of individual scores at each level. Thus, a score of 0 would mean all five levels are not degenerated; whereas a score of 15, the maximum score, means that all five levels have grade 3 degeneration. Pfirrmann's scoring system is now widely used as an accredited standard in IDD research. Several researchers defined three or more grades of IDD based on Pfirrmann's classification²²⁻²⁴⁾. The evaluation of IDD

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Table 1. Schneiderman's classification (adapted from Schneiderman et al.¹⁹)

Grade	Description
Normal	No signal changes
1	Slight decrease in nucleus pulposus signal intensity
2	Hypointense nucleus pulposus with normal disc height
3	Hypointense nucleus pulposus with narrowing disc space

Table 2. Pfirmann's classification (adapted from Pfirmann et al.²⁰)

Grade	Description
Grade 1	Disc structure is homogeneous with bright hyperintense white signal
	intensity and normal disc height.
Grade 2	Disc structure is non-homogeneous with a hyperintense white signal.
	The distinction between the nucleus and annulus is clear, and the disc
	height is normal with or without horizontal gray bands.
Grade 3	Disc structure is non-homogeneous with intermediate gray signal
	intensity. The distinction between the nucleus and annulus is unclear,
	and the disc height is normal or slightly decreased.
Grade 4	Disc structure is non-homogeneous with hypointense dark gray signal
	intensity. The distinction between the nucleus and annulus is lost, and
	the disc height is normal or moderately decreased.
Grade 5	Disc structure is inhomogeneous with hypointense black signal
	intensity. The distinction between the nucleus and annulus is lost, and
	the disc space is collapsed.

using these classifications reportedly has high intra- and interobserver agreement according to the kappa (statistic) coefficient. Therefore, we believe that evaluation of IDD using MRI has high reliability.

A major problem with Pfirrmann's classification is a semi-quantitative evaluation of IDD. For further quantitative evaluation of IDD, based on biochemical changes within discs, several MRI techniques have recently been developed such as T2 mapping²⁵, T1p imaging^{26,27}, MR spectroscopy²⁸, and diffusion-weighted imaging²⁹. Using the new techniques, we believe that both quantifiable and early-stage IDD evaluations are possible. Quantitative evaluation is available for measuring disc degeneration in longitudinal follow up studies. To date, few studies have used these new technologies within the athletic population^{27,30}.

Prevalence of lumbar IDD. Many studies have looked at the prevalence of IDD in the general and athletic populations. IDD, in particular, is a frequent injury in athletic populations. Although X-ray is the standard evaluation method for IDD, Swärd et al.³¹⁾ investigated the prevalence of IDD in 24 elite gymnasts and reported that 75% (18/24) had degenerated discs, a significantly greater prevalence than among non-athletes (31%). To our knowledge, among the scientific literature, this study reported the highest prevalence of IDD in an athletic population. We also investigated the prevalence of radiological abnormalities (including IDD) detected on MRI in 104 Japanese collegiate male and female gymnasts and found that IDD was the most common abnormality (40.4%) in this group.

In one of the largest MRI studies (including 308 Japanese collegiate athletes and 71 non-athletes), a high prevalence of IDD was seen in baseball (59.7%), swimming (57.5%), basketball (42.9%), kendo (39.2%), and soccer $(36.2\%)^{22}$. We also investigated the relationship between IDD and gene polymorphism in 601 Japanese collegiate athletes. The proportion of athletes who had IDD among wrestlers (53.0%) and judokas (50.8%) was higher than those in other sports²³⁾. Interestingly, Hangai et al.²²⁾ reported the prevalence of IDD in 43 runners (25.6%), which was significantly lower than the prevalence among non-athletes (31.4%). Min et al.²³⁾ investigated that the IDD prevalence was 22.7% (44/194) in track and field athletes. Regardless of the fact that participating in sports activities is a risk factor of IDD, the characteristics of the specific sporting events might be related to the risk. In addition, several studies have noted the prevalence of IDD in female dancers³²⁾, elite horseback riders³³⁾, adolescent rowers³⁴⁾, and elite junior tennis players¹⁸⁾.

IDD, particularly in the lower discs (L4–5 and L5–S1 discs), is commonly reported with single or contiguous, multilevel involvement, among the general population^{12,35)}. Similarly, the prevalence of IDD at each disc level for several competitive sports was reported by Hangai et al.²²⁾, who observed it predominantly in the lower discs. Our study investigated the prevalence of IDD on MRI in 104 Japanese collegiate gymnasts. Contrary to the report by Hangai et al., IDD mainly occurred in both the lower (L4–5 and L5–S1) and upper (L1–2, L2–3, and L3–4) discs in gymnasts³⁶⁾. We believe that the IDD injury level reflects the characteristics of particular sports. Furthermore, recent studies showed that 8.7% of the studied subjects in Southern Chinese had a unique pattern of IDD with a skipped level^{37,38)}. That phenomenon has not been reported in the athletic population in the scientific literature to date.

Possible risk factors for lumbar IDD. To determine the correlation between lumbar IDD and LBP, it is necessary to first clarify the risk factors of lumbar IDD because we believe that this correlation can be related to LBP prevention or improvement. Despite the high prevalence in the general and athletic populations, the risk factors for IDD have not been fully clarified. Some risk factors are reportedly associated with IDD, including intrinsic factors such as age¹², being overweight³⁹, decreased nutrition⁴⁰, familial predisposition⁴¹, genetic factors²³, and extrinsic factors such as smoking⁴² and sports activities^{22,23}.

Age. Several studies have reported that the prevalence of IDD is associated with aging. A study conducted in southern China reported that individuals aged 18-29, 30-39, 40-49, and ≥ 50 years had at least one level of IDD at a prevalence of 42%, 48%, 70%, and 88%, respectively¹²). A large population study recently associated lumbar IDD and age in elderly individuals⁴³. Moreover, signs of IDD can also be identified in adolescents. Salminen et al.⁴⁴ reported that the prevalence of IDD in individuals 15 years of age was 33%. LBP is also common among children and adolescents, and its prevalence increases with age. IDD and LBP may be revealed accordingly.

Overweight. Several studies have reported that the prevalence of IDD is associated with obesity. Samartzis et al.¹¹⁾ reported that the presence of juvenile disc degeneration (in patients < 21 years old) was strongly associated with being overweight and obese in southern Chinese volunteers. A previous prospective MRI study found that a body mass index (BMI) > 25 kg/m² increases the risk for IDD, with a stronger effect of high BMI at a young age (25 y) than in middle age (40-45 y)³⁹⁾. Okada et al.⁸⁾ suggested that the prevalence of IDD in the lightweight, middleweight, and heavyweight categories of collegiate judo athletes was 24.1%, 61.3%, and 90.9%, respectively. Thus, we think that obesity affects IDD more than age does in young individuals. Obesity has also been reported as a risk factor of LBP.

Nutrition. The intervertebral disc (or intervertebral fibrocartilage) is the largest avascular tissue in the body, as diffusion from blood vessels of the annulus and the vertebral endplate from the source of nutrition⁴⁵⁾. The correlation between IDD and endplate injuries has been studied in various ways, including animal^{46,47)}, cadaveric⁴⁸⁾, and MRI studies^{40,49)}. Wang et al.⁴⁸⁾ recently suggested that the disruption of endplate integrity may trigger a series of pathological cascades that eventually result in adjacent IDD, as observed in an autopsy study. Moreover, our

study suggested that anterior limbus vertebra is a significant predictor for IDD in Japanese collegiate gymnasts (adjusted odds ratio [OR], 6.60; 95% confidence interval [CI], 2.14-20.35)³⁶⁾.

Familial predisposition and genetic factors. Since the end of the 20th century, numerous studies have suggested that IDD may be largely heredity. Videman et al.⁵⁰⁾ studied IDD in 85 pairs of male monozygotic twins using spinal MRI. Two intragenic polymorphisms of the vitamin D receptor gene were associated with IDD. Since then, IDD in human beings has been reported to be associated with many genes, including those coding for collagen IX⁵¹⁾, collagen XI (COL11A1)⁵²⁾, matrix metalloproteinase-3 (MMP-3)⁵³⁾, interleukin-1 (IL-1)⁵⁴⁾, and cartilage intermediate layer protein (CILP)²³⁾.

The correlation between gene polymorphism and IDD in athletes has been examined in only a few reports^{23,55,56}). Our study found a significant association between CILP C allelic polymorphism and IDD in collegiate male judo athletes (OR, 4.1; 95% CI, 1.57-10.71)⁵⁵⁾. Our further study suggested that the CILP polymorphism is one of the genetic factors influencing the occurrence of IDD, especially in male collegiate athletes²³⁾. However, the gene encoding the a1 chain of COL11A1 (rs 1676486) was not a susceptibility factor for IDD in Japanese collegiate gymnasts. On the contrary, our study found that Japanese gymnasts with the TT genotype of the COL11A1 polymorphism (rs 1676486) are at increased risk for limbus vertebra⁵⁶⁾. Since the limbus vertebra is a significant risk factor for IDD in gymnasts⁵⁶, indirect relationships between COL11A1 polymorphism and IDD might exist.

A recent systematic review found moderate evidence of genetic variations such as ASPN (asporin) (Drepeat), COL11A1 (collagen XI alpha 1) (rs1676486), GDF5 (growth differentiation factor 5) (rs143383), SKT (Sickle tail) (rs16924573), THBS2 (thrombospondin 2) (rs9406328), and MMP9 (matrix metalloproteinase-9) (rs17576)⁵⁷⁾. According to Martin et al.⁵⁸⁾, evidence has indicated that apoptosis plays an important role in IDD. Interestingly, one recent study showed that CASP-9 (Caspase-9) gene polymorphism (apoptosis-associated gene) is associated with discogenic LBP⁵⁹⁾. This research may help prevent IDD and discogenic LBP; however, there has not been much research about gene polymorphism and IDD in the athletic population. Nevertheless, as previously described, IDD and LBP have many common risk factors.

Sports activities. As described in an earlier section, IDD is a frequent injury in athletic populations with the exclusion of runners. Our study reported that the prevalence of IDD was significantly higher in collision sports (American football, wrestling, judo, and soccer) than in non-collision sports (swimming, gymnastics, and track and field) among collegiate athletes²³⁾. One study on IDD in

elite swimmers showed that lumbar disc elite (high-load) swimmers were more frequently injured than recreational (low-load) swimmers²⁴⁾. In other words, this finding indicates that the physical load on sports activity has a significant effect on IDD occurrence.

Part II. Correlation between lumbar IDD and LBP

Lumbar IDD versus LBP in general population. Table 3 shows the studies to date that investigated the association between lumbar IDD and LBP in the general population^{11,12,38,43,60,61)}. A positive association between IDD and LBP has been observed in the general population by many research groups. Interestingly, one recent study indicated that the presence of IDD was significantly associated with LBP in the lumbar region, but not with neck pain in the cervical region in a large Japanese population⁴³⁾. We think that the finding of lumbar IDD may be associated with LBP in the general population. However, many studies have reported IDD in asymptomatic individuals^{13,14,17}). In other studies, asymptomatic patients had an abnormal prevalence of lumbar disc degeneration^{13,14,17)}. Cheung et al.¹²⁾ reported a direct correlation between LBP and IDD severity using Schneiderman's score. Asymptomatic individuals may have mild IDD. However, we believe that there is no association between LBP and mild IDD.

Lumbar IDD versus LBP in athletic populations. Table 4 shows previous studies that investigated the association between lumbar IDD and LBP in athletic populations. Researchers have demonstrated a significant co-prevalence between radiological abnormalities (including IDD) and

LBP in athletes participating in various sports^{7,22)}. In our previous study in which we used logistic regression analysis to analyze the concomitant environmental variables, IDD (OR, 2.70; 95% CI, 1.10-6.66) was a statistically significant variable accounting for LBP in Japanese collegiate gymnasts⁷⁾.

On the other hand, many studies have previously reported the absence of an association between lumbar IDD and LBP in athletic populations^{8,24,33,62)} (Table 4). Another study indicated that Japanese collegiate judo athletes had a higher rate of lumbar radiological abnormalities such as IDD. However, they found no significant association between lumbar radiological abnormalities and nonspecific LBP⁸⁾. Furthermore, several studies also found IDD in asymptomatic athletes as well as the general population^{15,16,18)}. Table 4 shows that the correlation between IDD and LBP seems ambiguous compared to that of the general population. We discuss basic and clinical research related to this topic in the following section.

Basic research. One basic research study revealed that isolated nerve fibers that express substance P deep within IDD, and their association with pain suggests an important role for nerve growth into the intervertebral disc in the pathogenesis of LBP⁶³⁾. Hence, this research supports the cause of LBP at the intervertebral disc. Interestingly, Peng's review of discogenic LBP suggested the pathological features of discs with discogenic LBP, such as granulation tissues with nerve innervation. In other words, asymptomatic IDD does not contain vascular granulation tissue, and only a few growth factors are expressed. In this case, IDD with tears are not painful because these

Studies	Study design	No. of cases	Age	IDD definition (Severity)	Severity of IDD	LBP definition	Association yes/no
Samartzis et al., 2011 ¹¹⁾	Cross-sectional	83	13-20	MRI (Schneiderman)	Schneiderman score	>2 weeks' duration	Yes
Cheung et al., 2009 ¹²⁾	Cross-sectional	1043	18-55	MRI (Schneiderman)	Schneiderman score	>2 weeks' duration	Yes
Cheung et al., 2012 ³⁸⁾	Cross-sectional	1457	9.7-88.4	MRI (Schneiderman)	Schneiderman score	> 2 weeks' duration	Yes
Teraguchi et al., 2014 ⁴³⁾	Cross-sectional	975	21-97	MRI (Pfirmann) Grade 4 or 5	No	In the past month	Yes
Schepper et al., 2010 ⁶⁰⁾	Cross-sectional	2819	65.7±6.6	X-ray	Grade 0 = none Grade 1 = mild Grade 2 = moderate Grade 3 = severe	In the last month >1 year: chronic LBP	Yes
Kim et al., 2012 ⁶¹⁾	Cross-sectional	60	Group A: 34.4 ± 8.6 Group B: 39.4 ± 9.3 Group C: 36.3 ± 12.0	MRI (Pfirmann) Grade 3 or more	No	Group A: Acute Severe LBP. Severe was defined patient had difficulty sitting on the bed	Yes

 Table 3.
 Lumbar disc degeneration and low back pain in the general population

IDD, intervertebral disc degeneration; LBP, low back pain

Study	Study design	No. of cases	age	IDD definition (Severity)	IDD severity	LBP definition	Association yes/no
Koyama et al., 2013 ⁷⁾	Cross-sectional	104 (gymnasts)	18-22	MRI (Pfirmann) Grade 3 or more	No	OCU test (total score of 1 point or more)	Yes
Okada et al., 2007 ⁸⁾	Cross-sectional	82 (Judo)	$\begin{array}{c} 20.1 \pm \\ 0.9 \end{array}$	MRI (Pfirmann) Grade3 or more	No	OCU test (total score of 1 point or more)	No
Hangai et al., 2009 ²²⁾	Cross-sectional	308 (athletes)	18-23	MRI (Pfirmann) Grade 3 or more	No	During their lifetime (yes or no) During the past 4 weeks (yes or no)	Yes
Kaneoka et al., 2007 ²⁴⁾	Cross-sectional	56 (swimming)	15-27	MRI (Pfirmann) Grade 3 or more	No	LBP history (yes or no) Severe LBP: interfered with daily living and training	No
Kraft et al., 2009 ³³⁾	Cross-sectional	58 (horseback riders)	18-41	MRI (modified Pfirmann) Grade 3 or more	No	Definition is unclear VAS Oswestry questionnaire	No
Bennett et al., 2006^{62}	Cross-sectional	19 (gymnasts)	12-20	MRI Mild or moderate severe	No	LBP currently limiting training to any degree	No

Table 4. Lumbar disc degeneration and low back pain in athletic populations

IDD, intervertebral disc degeneration; LBP, low back pain; VAS, visual analog scale

discs are not innervated⁶⁴⁾. We think that if the degree of IDD is high enough to induce granulation and nerve innervation, pain will occur.

Clinical research. We reviewed clinical papers investigating the correlation between IDD and LBP, especially in non-athletes^{11,12,38,43,60,61)}. All of the papers showed the same result, a significant correlation between IDD and LBP; therefore, we believe these clinical papers have several common features. First, these studies were large population studies^{12,38,43,60)}. Although the studies by Samartzis et al.¹¹⁾ and Kim et al.⁶¹⁾ had small sample sizes, they finely delineated the definition of LBP. In particular, to decrease the risk of recall bias in the assessment of LBP, Samartzis et al.¹¹⁾ consulted a family member of the participant to assess the accuracy of self-reporting. Second, these studies used logistic regression analysis to investigate the correlation between IDD and LBP^{12,38,43,60)}.

On the contrary, the correlation between IDD and LBP in athletic populations remains unclear. What is the difference between general population studies and athletic population studies? We think that the following five points are important in studies of athletes:

1) Sample size

- 2) Multifactorial statistical analysis
- 3) LBP definition
- 4) IDD severity level
- 5) Study design
- We discuss these five points following.

Sample size. Most of the studies regarding LBP and IDD in athletes had smaller sample sizes than those of non-athletes (Table 4). One of the major reasons for a smaller sample size is that it is difficult to enroll large groups of competitive athletes with relatively long sports experience. We also think that the small sample sizes of the athlete studies are a major reason for inconsistencies in the reported correlations between LBP and IDD.

Multifactorial statistical analysis. Many of the studies in athletes compared only case and control groups to investigate the correlations between IDD and LBP. However, we think that multifactorial analysis is also necessary. Because the cause of LBP is thought to be multifactorial (including gender, BMI, and sports experience), these factors should be included while analyzing correlations between LBP and IDD.

LBP definition. With regard to the definition of LBP, in the general population, the definition of LBP differs only slightly among studies. On the contrary, in athletic populations, the definitions differ in terms of duration, questionnaires about activities of daily living, and training limitations. Hangai et al.²²⁾ reported IDD and LBP in well-trained university athletes. Their definition of LBP was "experiences of LBP during their lifetime (yes or no) and during the past 4 weeks (yes or no)" on a questionnaire. Koyama et al.⁷⁾ also reported an evaluation of the association between IDD and LBP in gymnasts. We as-

sessed LBP using the questionnaire developed by Osaka City University about LBP related to activities of daily living⁷). In female gymnasts, current LBP was defined by Bennett et al.⁶² as any LBP currently limiting training to any degree. These discrepancies in the definition of LBP may affect associations between LBP and IDD. If the etiology of the LBP is the disc, flexion will worsen the symptoms and extension will relieve them. MRI is a sensitive and reliable imaging approach to evaluating IDD; however, the result often does not match the patient's clinical symptoms. Thus, we think that it causes relative confusion of IDD and LBP in the athletic population because many studies used a different definition of LBP. The authors hope that further studies incorporate standardized definitions of LBP.

Severity of IDD. With regard to IDD severity in the general population, as described above, a large population study reported a direct correlation between LBP and IDD severity using Schneiderman's score^{12,38}. Although Teraguchi et al.⁴³⁾ did not assess IDD severity, these definitions of IDD were grade 4 or 5. Hence, we believe that there is a positive association between severe IDD and LBP.

However, in the athletic population, the association between IDD severity level and LBP has not been clarified. Hence, we think that despite the existence of IDD, there may not be any LBP in a given athlete. It is possible that the IDD severity level plays an important role in the athletic population. To confirm that hypothesis, we conducted an additional analysis of IDD and LBP severity among 180 collegiate gymnasts. We also calculated Pfirrmann's score. Thus, a score of 5 would mean all five levels were grade 1, whereas a score of 25, the maximum score, would indicate that all five levels have grade 5 degeneration. Although 37.2% of the gymnasts has LBP, the score is a low 5. However, Fig. 1 shows the same tendency in a general population study¹². We believe that additional studies using the IDD severity level are needed to establish the association between IDD and LBP among the athletic population.

Study design. Additionally, we believe that study design is important in the analysis of cause-and-result relationships. Most studies of the correlations between LBP and IDD were cross-sectional and did not include athletic status. Even if the association between IDD and LBP was found in cross-sectional studies, the causal inference cannot be proved by them. These cross-sectional studies with pain assessments always involve unavoidable recall bias.

The correlation between IDD and LBP in athletes in prospective studies has been examined in only a few reports. Nagashima et al.³⁰⁾ reportedly did not find a correlation between IDD and LBP in high school American football players in a 2-year follow-up study. Similarly, there was no statistically significant correlation between LBP and MRI change (including IDD) in a 15-year follow-up study in top athletes.⁶⁵⁾ To our knowledge, there are few prospective studies in athletes. Furthermore, we hope that standardized LBP definitions will be used in future pro-





Fig. 1 Relationship between total Pfirrmann's score and low back pain (LBP)

We conducted additional analysis of intervertebral disc degeneration (IDD) and LBP severity of 180 collegiate gymnasts. We calculated both Schneiderman's score¹²⁾ and Pfirrmann's score. A score of 5 meant that all five levels had grade 1 degeneration, whereas a score of 25, the maximum score, meant that all five levels had grade 5 degeneration. Although 37.2% of the gymnasts have LBP, the score was only 5. However, the same tendency was seen in a general population study¹²⁾.

spective studies of athletic populations.

Possible mechanisms for IDD and LBP in athletes.

There are many risk factors associated with IDD (Fig. 2), including intrinsic factors such as age, overweight, decreased nutrition, familial predisposition, and genetic factors; and there are extrinsic factors such as smoking and participating in sports activities. We believe that the most important risk factor is age because the prevalence of IDD was greater than 90% in men and women aged over 50 years according to Teraguchi et al.⁴³⁾ In athletes, repetitive microtrauma may accelerate disc degeneration by participation in sports. Additionally, we think that such participation may also affect other risk factors of IDD. For example, our study found that the prevalence of LBP in Japanese gymnasts was 49.0% (51/104) and MRI abnormalities were IDD (40.4%) and trauma to the limbus vertebra (18.3%). Trauma to the limbus vertebra occurs during early external forces in child gymnasts due to spinal hyperextension/flexion. Our MRI study indicated that trauma to the limbus vertebra was a predictor of IDD in Japanese gymnasts. Although we must further examine the cause, we think that the risk factor of decreased nutrition might accelerate the development of trauma to the limbus vertebra.

Multiple risk factors are also reportedly associated with LBP and athletes exposed to various external stresses. Therefore, these factors are likely to be diverse, especially in athletes. Diverse external stress might cause various radiological changes in athletes. For example, vertebral endplate signal changes (modic change), limbus vertebra trauma, spondylosis, and lumbar disc hernias have been seen in collegiate athletes (Fig. 3). Therefore, these diverse factors must also be considered in coming to conclusions about the correlation between IDD and LBP for athletic populations.

Interestingly, Iwai et al.⁶⁾ suggested that low strength of the trunk extensors is one of the factors associated with LBP and the functional disability level in collegiate wrestlers without radiological abnormalities. We should consider both radiological abnormalities and physical characteristics as risk factors of LBP in athletes.

Conclusion

This review focused on the classification, definition, prevalence, and risk factors in lumbar IDD and discussed the correlation between IDD and LBP. We found that even



Fig. 2 Scheme of the association between intervertebral disc degeneration (IDD) and low back pain (LBP) in athletes



Fig. 3 Intervertebral disc degeneration (IDD) and other abnormalities Magnetic resonance imaging (MRI) of the lumbar spine showing multilevel disc degeneration and other abnormalities such as disc protrusion and trauma to the limbus vertebra.

if there was an association between IDD and LBP in MRI cross-sectional studies, the causal inference could not be proven. Therefore, we recommend the use of standardized definitions of LBP in future prospective studies in athletic populations as well as considering the absence of other MRI abnormalities and IDD severity level.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this article.

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