


Radiological osteoarthritic knee joint changes in high school and collegiate sumo wrestlers

The observational study

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Abstract

We examined the effects of sumo on their knee joints, and investigated the relationship between radiological changes and knee joints symptoms, and the relationship between knee radiological changes and the physical characteristics of the wrestlers. Fifty-six high-school and 128 college freshman sumo wrestlers who belonged to the Japanese Sumo Federation. To evaluate radiological changes in the knee joints of high-school and college freshmen sumo wrestlers. They underwent routine radiographic examination of their knee joints and were instructed to answer a questionnaire regarding their knee symptoms as a medical check. The mean height, weight, body mass index (BMI), and sumo career/experience of the participants were 174.1 cm, 106.9 kg, 35.1 kg/m², and 7.9 years, respectively. Twenty-five high-school (44.6%) and 54 collegiate (42.2%) sumo wrestlers had some knee symptoms, which was significantly associated with sumo career as a risk factor. Five high-school (8.9 %) and 18 collegiate (14.1 %) sumo wrestlers had joint space narrowing. Considering the relationship between knee symptoms and radiological changes, significant correlations between osteophyte formation and bony sclerosis and knee symptoms were observed. According to the Kellgren-Laurence (KL) classification, 7 high-school (12.5%) and 26 collegiate (20.3%) sumo wrestlers were grade 2, 3, or 4. The risk factors of degenerative radiographic changes in the knee joints of the participants were heavyweight, large BMI, and older age. The knee osteoarthritic changes had already appeared in 12.5% high-school sumo wrestlers at the admission.

Abbreviations: BMI = body mass index, FTA = femorotibial angle, KL = Kellgren-Laurence, KOA = knee osteoarthritis, OA = osteoarthritis.

Keywords: knee joint, osteoarthritis, radiological changes, sumo wrestling

1. Introduction

Sumo has long been a traditional sport in Japan. The first World Sumo Championship was held in 1992, when the International Sumo Federation was established. The World Sumo Championships have been held in various countries, including Japan, Germany, and Brazil. The 23rd World Sumo Championship and the 14th World Women's Sumo Championship was also held in Japan in 2019. Thus, sumo is enjoyed and practiced by many people, and has recently grown to become a worldwide sport. As sumo becomes more popular in the international arena, further focus on health and injuries of sumo athletes is warranted.

A high occurrence of injuries among sumo wrestlers has been suspected to occur because sumo wrestlers of various

heights and weights fight each other (e.g., tall with short, and heavy with light). Nakagawa investigated the characteristics and statistics of injuries among sumo wrestlers in 101 collegiate and 203 high school sumo wrestlers.^[1] In sumo wrestling, injury associated pain is most frequently reported in the lower back, neck, knees, and shoulders, whereas in major class collegiate wrestling, disabilities from injuries of the knee, shoulder, neck and ankle are most commonly reported.^[1] In major class high-school wrestling, injury associated pain is most frequently reported in the lower back, wrist, neck and fingers, and disabilities from injuries of the neck, lower back, finger and shoulder are most commonly reported. The risk factors for knee injuries were heavier weight and larger body mass index (BMI). The longer a sumo wrestler's career is, the higher the risk of neck, wrist, finger, and shoulder injuries;

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The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

All procedures were reviewed and approved by the research ethics committee of our hospital.

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however, no risks of lower back and knee injuries were observed.^[1] Beginner sumo wrestlers are taught how to prevent lower back and knee injuries, especially when the sumo wrestlers have a large BMI.

Recently, the use of imaging modalities for diagnosing and assessing knee osteoarthritis (KOA) has increased dramatically.^[2] Magnetic resonance imaging has become a major advanced imaging tool for characterizing KOA in the research setting; however, radiography is the most commonly used imaging modality for diagnosing and assessing patients in the primary care setting.^[2,3] Plain film radiography is the currently accepted, low-cost method for monitoring osteoarthritis (OA) progression.^[4]

Few studies have reported radiological changes in sumo wrestlers' knee joints. Nakagawa has reported that among collegiate sumo wrestlers, 44% have some abnormal findings in their knee joints, which are associated with risk factors, namely, heavyweight, and BMI.^[5] However, the radiological changes in the knee joints of high-school and freshmen sumo wrestlers and the relationship between radiological changes and knee symptoms are not known, till now. This study was conducted to evaluate radiological changes in the knee joints of high-school and freshmen sumo wrestlers to examine the effects of sumo training on their knee joints before college, to investigate the relationship between radiological changes and knee symptoms, and the relationship between knee radiological changes and the physical characteristics of the wrestlers, and to compare the radiological knee joint changes in high-school sumo wrestlers with those in freshman collegiate sumo wrestlers. Therefore, this study had 2 objectives: 1 is to describe the radiological changes in sumo wrestlers, and the other is to describe the correlation between the radiological changes and knee symptoms or physical characteristics.

2. Materials and Methods

It is a prospective cohort study. Over a decade, 56 high-school and 133 freshmen collegiate sumo wrestlers who belonged to a major class in the Japanese Sumo Federation underwent medical examination using radiography, completed questionnaires regarding their knee symptoms, and were assessed relative to their physical characteristics. They had been admitted to a high-school or university based on their superior sumo wrestling performance during junior high-school or senior high-school. Sumo wrestlers from 2 high schools and 3 universities participated in the medical examinations from March to May in each academic year, with a participation rate of 100%. In this research, we excluded 5 freshmen collegiate sumo wrestlers because they underwent knee operations before the medical examination, and we examined 56 high-school and 128 collegiate wrestlers. All wrestlers were male.

Each participant received 2 routine radiographs of their knees, an anteroposterior view and a lateral view. The radiographic examinations of both knees using an anteroposterior view with weight-bearing and foot-map positioning were performed. Fluoroscopic guidance with a horizontal anteroposterior X-ray beam was used to properly visualize the joint space. These radiographs were assessed for the femorotibial angle (FTA), joint space narrowing, osteophyte formation, bony sclerosis, and sharpness of the intercondylar eminence. The FTAs were assessed in the anteroposterior views. We also examined the ratio of grade 2, 3, or 4 in the Kellgren-Laurence (KL) classification.^[6]

Questionnaires regarding the subjects' knee symptoms included questions on whether they had knee pain continuing for more than 1 week, either at present or in the past during sumo wrestling. Those who responded "Yes" were assigned to the symptomatic group, whereas those who responded "No" were assigned to the asymptomatic group. In addition, we assessed their physiques, including height, weight, BMI, age, sumo career/experience, and training time per week.

Statistical analysis was performed using the Mann-Whitney *U* test to evaluate the relationship between knee radiological changes and physical characteristics. The chi-square test was performed to analyze the relationship between the radiological changes and knee symptoms, and compare the occurrence rate of the knee radiographic abnormalities between high-school and collegiate sumo wrestlers. *P* values of <.05 were used to denote statistical significance.

2.1. Ethical consideration

Informed consent was obtained from all subjects before participation, and all procedures were reviewed and approved by the Research Ethics Committee of our hospital (KMC 15-054).

3. Results

The mean height, mean weight, mean BMI, and sumo career/experience of the subjects were 174.1 cm, 106.9 kg, 35.1 kg/m², and 7.9 years, respectively. The mean values of the physical parameters in the high-school and collegiate groups are shown in Table 1. The height, weight, BMI, and sumo career/experience of high-school sumo wrestlers were significantly smaller than those of collegiate sumo wrestlers; however, the training time (hours/week) in high-school sumo wrestlers was significantly longer than that in collegiate wrestlers. The symptomatic group consisted of 79 sumo wrestlers (42.9%), and the asymptomatic group consisted of 105 sumo wrestlers. Twenty-five high-school (44.6%) and 54 collegiate (42.2%) sumo wrestlers had some knee symptoms. Among high-school sumo wrestlers, 12 and 13 had unilateral and bilateral knee symptoms, respectively. Among collegiate wrestlers, 33 and 21 had unilateral and bilateral knee symptoms, respectively. The knee symptoms were significantly associated with sumo career/experience (Fig. 1).

The mean FTA in high-school wrestlers was 177.3 degrees, and that in collegiate wrestlers was 177.5 degrees. No significant difference in the mean FTA was observed between high school and college cohorts. Twenty-three wrestlers (12.5%), including 5 high-school (8.9%) and 18 (14.1%) collegiate wrestlers (Tables 2), had knee joint space narrowing, and all joints had medial type (Fig. 2A). Among high-school sumo wrestlers, 3 and 2 had unilateral and bilateral joint space narrowing, respectively. Among collegiate wrestlers, 7 and 11 had unilateral and bilateral joint space narrowing, respectively. Joint space narrowing was significantly associated with heavyweight and large BMI (Fig. 2B and C).

Nineteen wrestlers (10.3%), including 4 high-school (7.1%) and 15 collegiate (11.7%) wrestlers (Table 2), had osteophyte formation (mainly medial type and tibia) in their knee joints (Fig. 3A). Among high-school sumo wrestlers, 4 had unilateral osteophytes, and no 1 had bilateral. Among collegiate wrestlers, 10 and 5 had unilateral and bilateral osteophytes. The risk

Table 1
The physical characteristics of the subjects.

Items	High school (56 cases)	Collegiate (128 cases)	<i>P</i> values
Height (cm)	171.9 ± 6.9	174.9 ± 6.2	.0039
Weight (kg)	94.1 ± 22.5	112.5 ± 19.6	<.0001
Body mass index (kg/m ²)	31.6 ± 6.4	36.7 ± 5.6	<.0001
Age (yr)	15.4 ± 0.59	18.2 ± 0.44	<.0001
Sumo career (yr)	6.33 ± 2.53	8.57 ± 3.17	<.0001
Training time (h/wk)	18.0 ± 5.9	15.5 ± 6.6	.0147

Mean ± standard deviation.

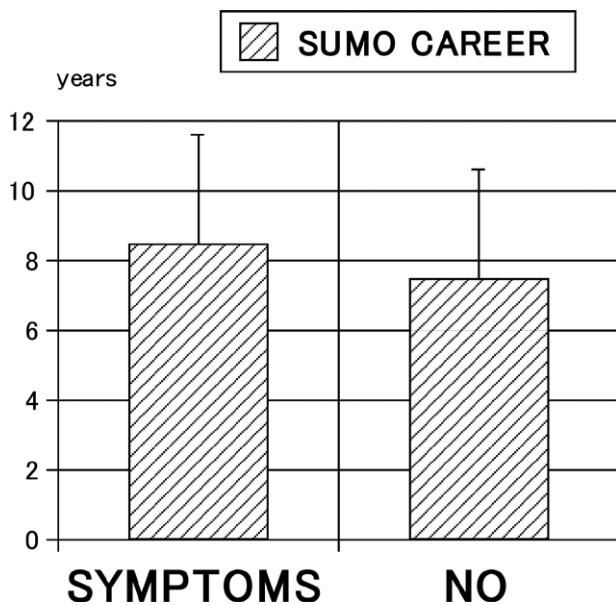


Figure 1. A risk factor of knee symptoms: sumo career/experience. The mean sumo career/experience in the symptomatic group was 8.46 years, and that in the asymptomatic group was 7.46 years. *P* value was .0342.

Table 2a

The occurrence numbers and rate (case numbers).

Items	High school (56 cases)	Collegiate (128 cases)	<i>P</i> values
Knee symptoms	25 (44.6 %)	54 (42.2 %)	.7569
Joint space narrowing	5 (8.9%)	18 (14.1 %)	.3326
Osteophyte formation	4 (7.1 %)	15 (11.7 %)	.3480
Bony sclerosis	1 (1.9 %)	4 (3.1 %)	.6072
Sharpness of intercondylar eminence	9 (16.1 %)	38 (29.7 %)	.0513
Abnormal radiographic findings	14 (25.0 %)	49 (38.3 %)	.0806

Table 2b

The occurrence numbers and rate (knee joint numbers).

Items	High school (112 joints)	Collegiate (256 joints)	<i>P</i> values
Knee symptoms	38 (32.9 %)	75 (29.3 %)	.3755
Joint space narrowing	7 (6.3 %)	29 (11.3 %)	.1313
Osteophyte formation	4 (3.6 %)	20 (7.8 %)	.1295
Bony sclerosis	1 (0.89 %)	6 (2.3 %)	.3485
Sharpness of intercondylar eminence	11 (9.8 %)	52 (20.3 %)	.0140
Abnormal radiographic findings	19 (17.0 %)	78 (30.5 %)	.0068

L = left side, R = right side.

factors associated with osteophyte formation were heavyweight and large BMI (Fig. 3B and C).

Five wrestlers (2.7%), including 1 high-school (1.9%) and 4 collegiate (3.1%) wrestlers (Table 2) had bony sclerosis in their knee joints, and all joints had tibial side (Fig. 4). No risk factors were associated with bony sclerosis. Forty-seven wrestlers (25.5%), including 9 high-school (16.1%) and 38 collegiate

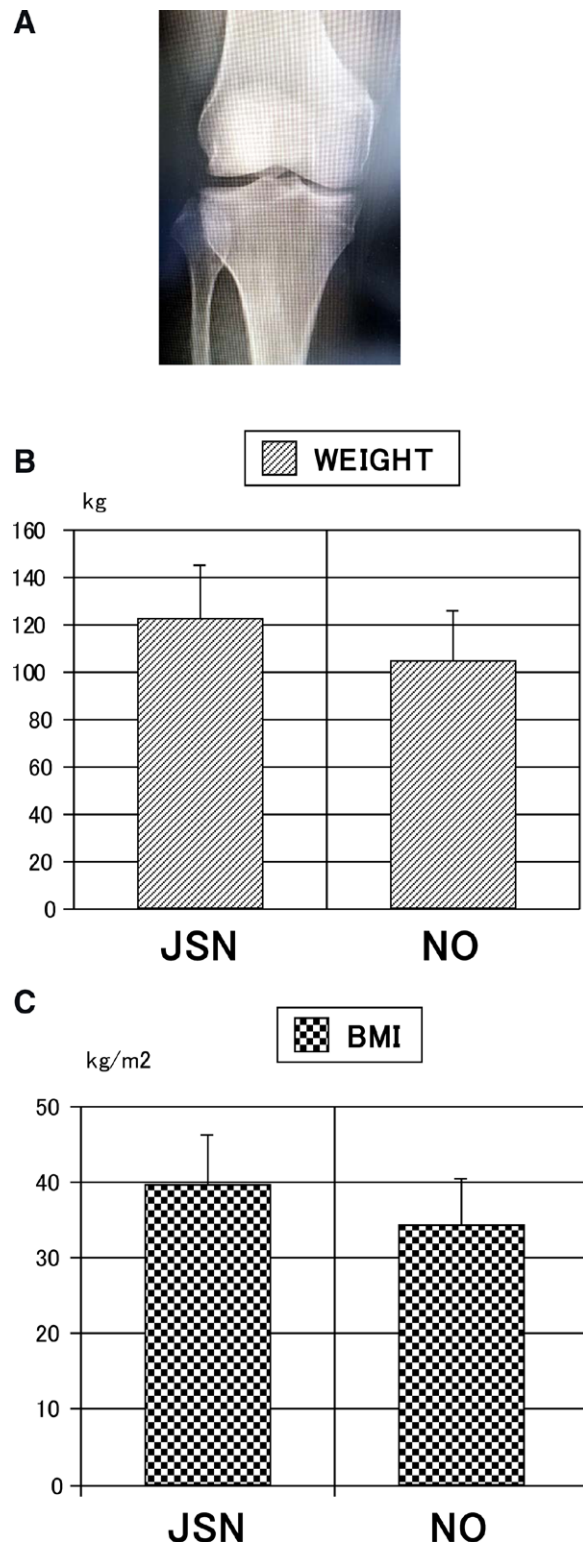


Figure 2. (A) Joint space narrowing in the medial side of right knee joint. (B) The mean weight in wrestlers with joint space narrowing was 122.4kg, and that in those without joint space narrowing was 104.7kg. *P* value was .0003. (C) The mean body mass index in wrestlers with joint space narrowing was 39.8kg/m², and that in those without joint space narrowing group was 34.5kg/m². *P* value was .0001. JSN = joint space narrowing group, NO = no joint space narrowing group.

(29.7%) wrestlers (Table 2), had sharpness of the intercondylar eminence in their knee joints (Fig. 5A). Among high-school sumo wrestlers, 7 and 2 had sharpness of the intercondylar

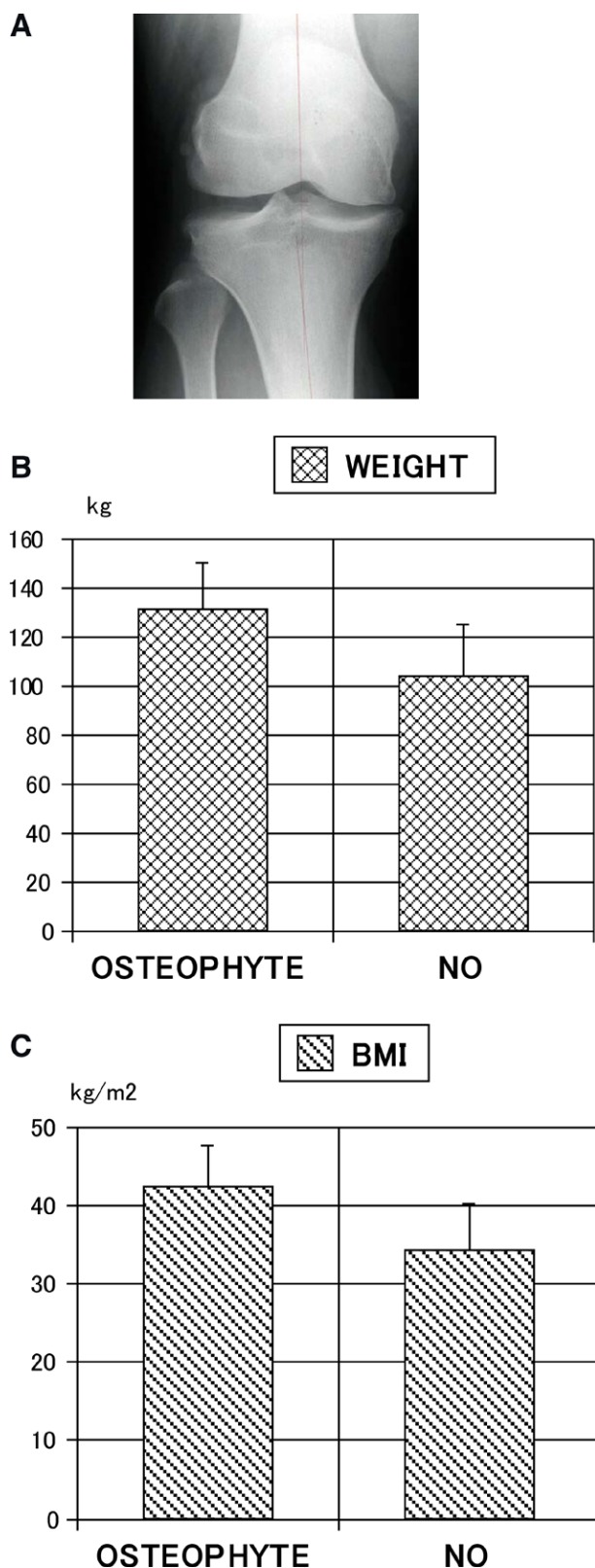


Figure 3. (A) Osteophyte formation in the medial tibia. (B) The mean weight in wrestlers with osteophyte formation was 131.8kg, and that in those without osteophyte formation was 104.0kg. *P* value <.0001. (C) The mean body mass index in wrestlers with osteophyte formation was 42.4kg/m², and that in those without osteophyte formation was 34.3kg/m². *P* value <.0001.

eminence in unilateral and bilateral knee joints, respectively. Among collegiate wrestlers, 24 and 14 had sharpness of the intercondylar eminence in unilateral and bilateral knee joints, respectively. Weight was prone to be a risk factor of sharpness of intercondylar eminence (Fig. 5B). The risk factors of sharpness of intercondylar eminence were large BMI and older age (Fig. 5C and D).

Sixty-three wrestlers (34.2%), including 14 high-school (25.0%) and 49 collegiate (38.3%) wrestlers (Table 2) had degenerative radiographic changes, such as joint space narrowing, osteophyte formation, bony sclerosis, and sharpness of the intercondylar eminence. Among high-school sumo wrestlers, 9 (16.1%) and 5 (8.9%) had unilateral and bilateral degenerative radiographic knee changes. Among collegiate wrestlers, 20 (15.6%) and 29 (22.7%) had unilateral and bilateral degenerative radiographic knee changes. The risk factors of degenerative radiographic changes in their knee joints were heavyweight, large BMI and older age (Fig. 6A–C). Compared with the occurrence ratio of knee radiographic changes between high-school and collegiate groups, the occurrence ratio of sharpness of intercondylar eminence in the collegiate group was larger than one in the high-school group. Seven high-school (12.5%) and 26 collegiate (20.3%) sumo wrestlers were grade 2, 3, or 4 in the KL classification.

Concerning the relationship between knee symptoms and radiological changes, significant correlations were observed between osteophyte formation and knee symptoms (*P* = .0178; the chi-square test) and between bony sclerosis and knee symptoms (*P* = .0090; the chi-square test). Thirteen (16.5%) of the 79 wrestlers in the symptomatic group and 6 (5.7%) of 105 wrestlers in the asymptomatic group had osteophyte formation, and 5 (6.3%) of the 79 wrestlers in the symptomatic group and 0 (0%) of the 105 wrestlers in the asymptomatic group had bony sclerosis.



Figure 4. Bony sclerosis in the medial tibia.

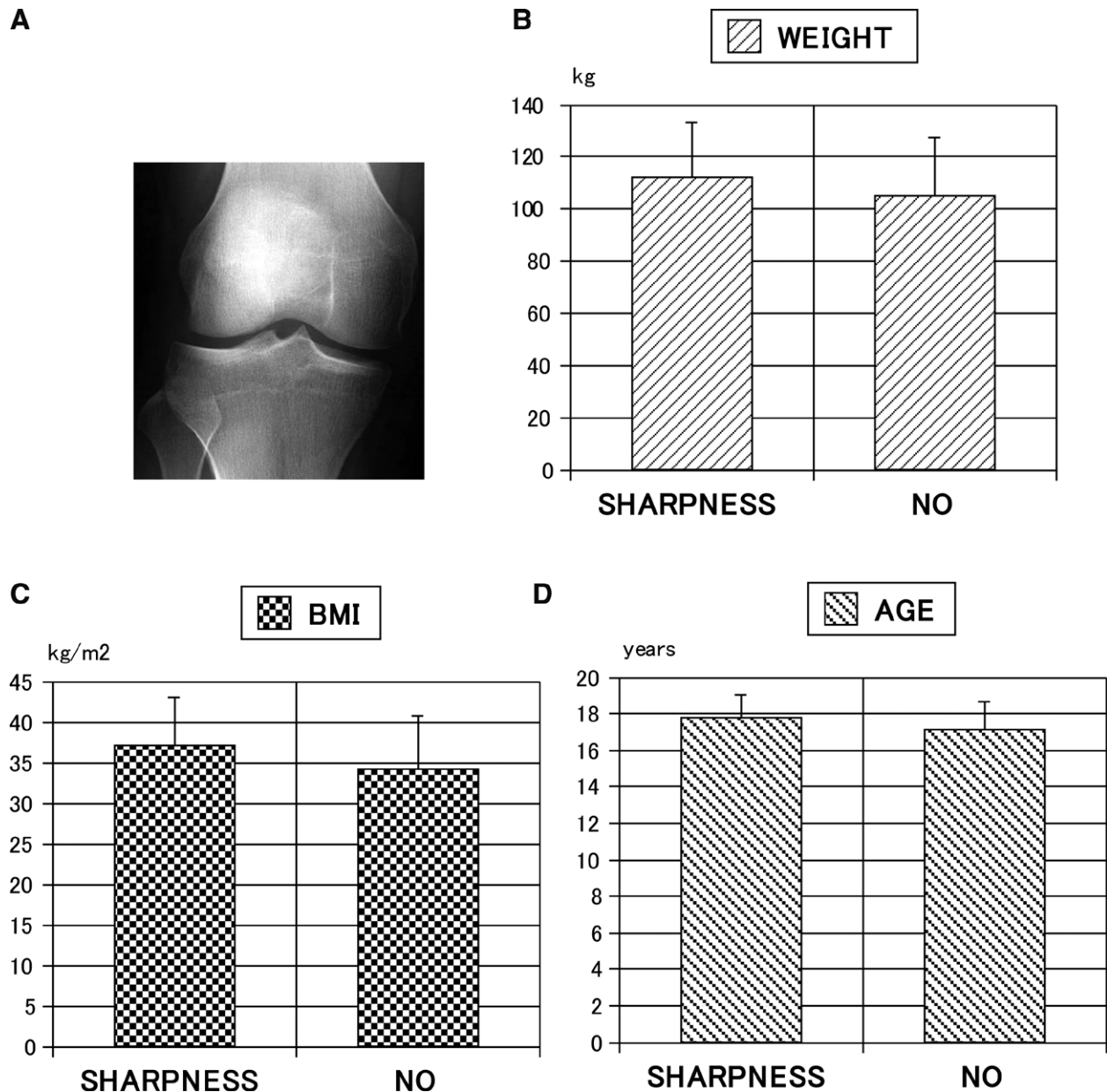


Figure 5. (A) Sharpness of the intercondylar eminence in the right knee joint. (B) The mean weight in wrestlers with sharpness of the intercondylar eminence was 112.3kg, and that in those without sharpness of the intercondylar eminence was 105.1 kg. *P* value was .0538. (C) The mean body mass index in wrestlers with sharpness of the intercondylar eminence was 37.2 kg/m², and that in those without sharpness of the intercondylar eminence group was 34.4 kg/m². *P* value was .0074. (D) The mean age of wrestlers with sharpness of the intercondylar eminence was 17.8 years, and that of those without sharpness of the intercondylar eminence was 17.2 years. *P* value was .0148.

4. Discussion

In summary, 25 high-school (44.6%) and 54 collegiate (42.2%) sumo wrestlers had some knee symptoms. Sumo career/experience was the risk factor of knee symptoms. Five high-school (8.9%) and 18 collegiate (14.1%) sumo wrestlers had joint space narrowing. Furthermore, 4 high-school (7.1%) and 15 collegiate (11.7%) sumo wrestlers had osteophyte formation. Heavyweight and large BMI were the risk factors associated with joint space narrowing and osteophyte formation. One high-school (1.9%) and 4 collegiate (3.1%) sumo wrestlers had bony sclerosis. No risk factors were found associated with bony sclerosis. Nine high-school (16.1%) and 38 collegiate (29.7%) sumo wrestlers had sharpness of the intercondylar eminence, which is significantly associated with large BMI and older age.

Concerning the occurrence rate of knee radiographic changes, the occurrence rate of sharpness of intercondylar eminence in the collegiate group was larger than that in the high-school group. Seven high-school (12.5%) and 26 collegiate (20.3%) sumo wrestlers were grade 2, 3, or 4 in the KL classification.^[6] With regard to the relationship between knee symptoms and radiological changes, significant correlations were observed between osteophyte formation and knee symptoms, and between bony sclerosis and knee symptoms.

Moreover, Nakagawa has reported that 44% of collegiate sumo wrestlers had some radiographic abnormal findings of the knee joints and that the risk factors associated with these abnormal findings were heavyweight and large BMI.^[5] In this study, 7 high school (12.5%) and 26 collegiate (20.3%) wrestlers

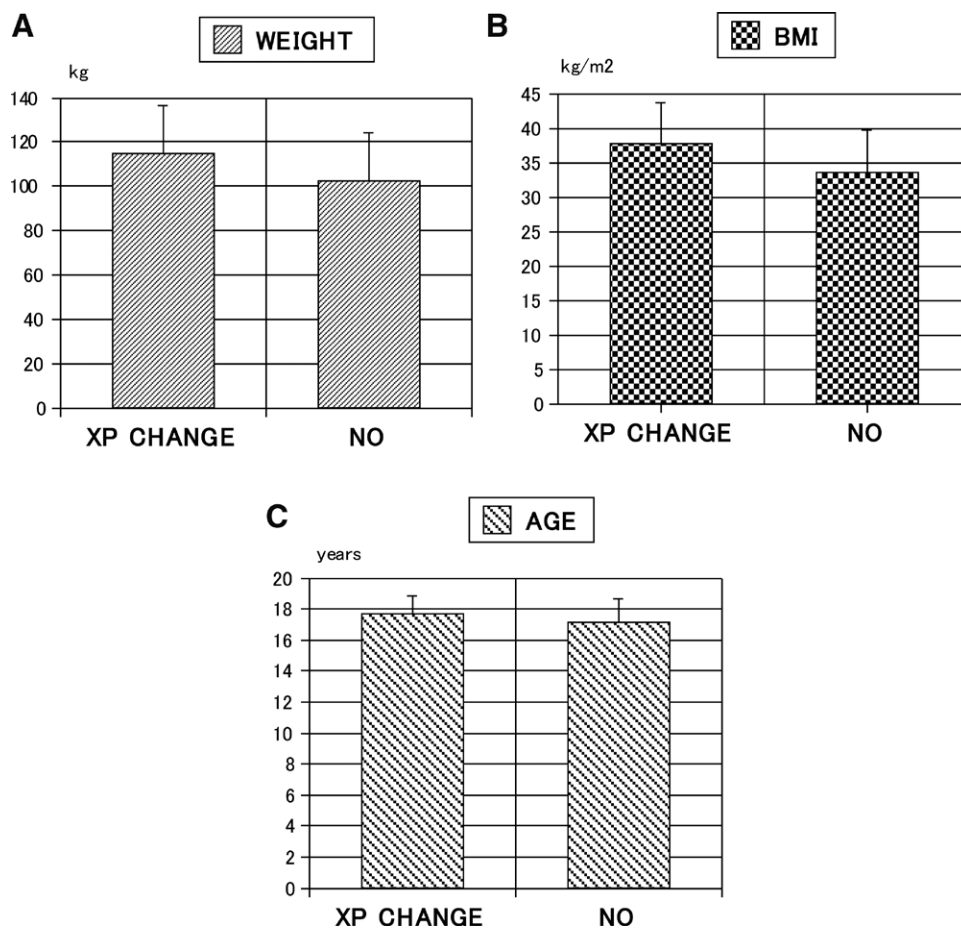


Figure 6. (A) The mean weight in wrestlers with degenerative radiographic changes was 115.0 kg, and that in those without degenerative radiographic changes was 102.7 kg. *P* value was .0003. (B) The mean body mass index in wrestlers with degenerative radiographic changes was 33.7 kg/m², and that in those without degenerative radiographic changes was 23.9 kg/m². *P* value < .0001. (C) The mean age of wrestlers with degenerative radiographic changes was 17.7 years, and that of those without degenerative radiographic changes was 17.2 years. *P* value was .0174.

were grade 2, 3, or 4 in the KL classification. The risk factors associated with degenerative radiographic changes in the knee joints of the subjects were heavyweight, large BMI and older age (Fig. 6A–C). Knee osteoarthritic changes of sumo wrestlers appeared as early as high-school age. The risk factors associated with KOA include old age, heavyweight, previous knee injuries, and previous work involving overloading the knees.^[7–10] Ackerman has demonstrated that the odds of arthritis and OA is up to 7 times higher in obese individuals than that in underweight/normal weight individuals.^[11] Molina-Garcia has insisted that the biomechanical alterations during walking in overweight/obesity could play a major role in the onset and progression of KOA.^[12] Sumo wrestlers must have a heavyweight, and sumo wrestling overloads their knee joints. These are risk factors of KOA. Quadriceps strength is an important determinant of physical disability, and quadriceps weakness is commonly observed in radiographic KOA.^[13] A reduction in thigh muscle strength may be primarily associated with the onset of the early stages of radiographic KOA, and the reduction in muscle strength is associated with the onset or progression of radiographic KOA.^[14,15] Therefore, we recommend the performance of muscle training around the knee joints to sumo wrestlers. In addition, we suggest that they should decrease their weight when retiring from sumo.

With respect to the relationship between sports activities and KOA, Qiu has reported that an increase in T2 relaxation time occurs in the medial tibial plateau of novice half-marathon runners.^[16] Compared with controls, elite Australian Rules footballers, aged, on average, 53.7 years, have a significant risk

of both functional and radiological OA.^[17] Among retired professional footballers for, on average 25 years, the prevalence of lower extremity OA was 33%.^[18] Serious degenerative changes were found in several retired female football players' knees 10 years after they retired. Their average age was 37 years, and 51% of these players met the magnetic resonance imaging criterion of KOA.^[19] The prevalence of radiographic KOA in the right, left and both knees (27.2%, 34.6%, and 14.4%) of former footballers was significantly higher than that of right, left, and both knees of the general population.^[20] Knee injury is the main attributable risk factor. Even after adjustment for recognized risk factors, KOA appears to be an occupational hazard in professional football.^[20] In this study, 12.5% and 20.3% of high-school and collegiate wrestlers, respectively, had radiographic KOA, except for those who had previous knee surgery. Sumo wrestling is a risk factor of KOA; in addition, we think that professional football is a risk factor of KOA as well.

KOA is radiographically defined as grades 2, 3, and 4 in the KL classification. In the general Japanese population, the prevalence of KOA in the age groups of less than 40, 40 to 49, 50 to 59, and 60 to 69 years were 0%, 9.1%, 24.3%, and 35.2%, respectively, in men.^[21] In female teachers in England, the prevalence of KOA in the age group of 46 to 60 years was 17.9%.^[22] The risk factors associated with KOA include older age, heavyweight, previous knee injury, previous work involving overloading the knees,^[7–9] large BMI,^[10] and high level of activity.^[23] In this study, 12.5% of the high-school and 20.3% of the collegiate sumo wrestlers had KOA. The ratio of KOA in high school and collegiate sumo wrestlers is higher than in the general Japanese population in the

age groups of less than 40. The risk factors associated with joint space narrowing and osteophyte formation were heavyweight and large BMI, as previously described. We think that sumo wrestling is a sport involving overloading the knees and a higher level of activity. In the Japanese male population, the mean FTA was 177.0 degrees.^[24] Koshino has measured the FTA of 85 knees in men and 97 knees in women aged 25 to 35 years and reported normal FTA values of 178 degrees and 176 degrees in men and women, respectively.^[25] In this study, as same as the above 2 reports, the mean FTA in high-school wrestlers was 177.3 degrees, and that in collegiate wrestlers was 177.5 degrees.

The relationship between the radiographic findings and symptomatic pain in the knee joints remains controversial, but at least the severity of radiographic OA is not linearly correlated with that of pain.^[26–28] Oka and Muraki have reported that multivariate analysis could detect significant associations of knee pain with medial joint space narrowing and high FTA, however, they were not strong.^[29,30] In this study, significant correlations were observed between osteophyte formation ($P = .0178$), bony sclerosis ($P = .0090$), and knee symptoms. With respect to the radiological changes without knee symptoms, Magnusson has insisted that structural changes suggestive of OA in knees without symptoms should probably better be regarded as risk factors of early OA rather than a disease.^[31]

In this study, among high-school sumo wrestlers, 9 (16.1%) had unilateral KOA and 5 (8.9%) had bilateral KOA. Among collegiate wrestlers, 20 (15.6%) and 29 (22.7%) had unilateral and bilateral KOA, respectively. Muraki has reported that the prevalence of unilateral and bilateral KOA was 12.3% and 49.5%, respectively.^[29] The difference in the prevalence of bilateral KOA seems to be associated with age. Moreover, in this study, joint space narrowing of all joints had a medial type, and osteophyte formation in the knee joints was mainly medial type and tibia. Similarly, Oka has reported that medial OA accounts for 97.8% of the total OA cases, with the lateral type accounting for the remaining 2.2%.^[24] Liu has insisted that the medial compartment had a higher prevalence of OA than the lateral compartment because the elevated strains might make the medial compartment more susceptible to degenerative changes than the lateral compartment.^[32] Again, in this study, 9 high-school (16.1%) and 38 collegiate (29.7%) sumo wrestlers had sharpness of the intercondylar eminence. Li has proposed that both the medial and lateral tibiofemoral contact points were located on the inner portions of the tibial plateau and femoral condyles (close to the tibial spine), indicating that the tibial spine plays an important role in knee stability.^[33]

The limitations of this study are in the following: moderate cases (184 cases), no longitudinal study (observational study), and only radiographic study without examination of the meniscus or cartilage.

In conclusion, we examined the radiological changes in the knee joints of 56 freshmen high school and 128 freshmen collegiate sumo wrestlers as their medical check. Seven high-school (12.5%) and 26 collegiate (20.3%) wrestlers were grade 2, 3, or 4 in the KL classification. The risk factors associated with the degenerative radiographic changes in the knee joints included heavyweight, large BMI and older age. With regard to the relationship between knee symptoms and radiological changes, significant correlations were observed between osteophyte formation and knee symptoms, and between bony sclerosis and knee symptoms.

Author contributions

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