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ORIGINAL ARTICLE

Osteoarthritis hip joints in Japan: involvement of acetabular dysplasia

Seiya Jingushi · Satoko Ohfuji · Muroto Sofue · Yoshio Hirota · Moritoshi Itoman · Tadami Matsumoto · Yoshiki Hamada · Hiroyuki Shindo · Yoshio Takatori · Harumoto Yamada · Yuji Yasunaga · Hiroshi Ito · Satoshi Mori · Ichiro Owan · Genji Fujii · Hirotsugu Ohashi · Yukihide Iwamoto · Keita Miyanishi · Toshiro Iga · Naonobu Takahira · Tanzo Sugimori · Hajime Sugiyama · Kunihiko Okano · Tatsuro Karita · Kenichi Ando · Takanari Hamaki · Teruhisa Hirayama · Ken Iwata · Satoshi Nakasone · Masanori Matsuura · Taro Mawatari

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Abstract

Background We conducted a nationwide epidemiologic study regarding hip osteoarthritis (OA) in Japan, and a previous report found these patients to be unique in comparison to Caucasians. This report focused on the data regarding each hip joint, and the involvement of acetabular dysplasia with hip OA was analyzed.

Methods Seven hundred twenty OA hips were examined. Sixty-five joints with osteonecrosis of the femoral head and 215 non-OA contralateral joints of the unilateral patients were examined as controls. The revised system of stage classification for hip OA of the Japanese Orthopedic Association (JOA) was used according to the reproducibility in order to ensure reliable data from the multiple

S. Jingushi (✉) · M. Itoman · K. Miyanishi
Department of Orthopaedic Surgery, Kyushu Rosai Hospital of Japan Labour Health and Welfare Organization, 1-3-1 Takamatsu, Kuzuhara, Kokura-minami-ku, Kitakyushu 800-0296, Japan
e-mail: jingushi.orth@kyushuh.rofuku.go.jp

S. Ohfuji · Y. Hirota
Department of Public Health, Osaka City University Graduate School of Medicine, Osaka, Japan

M. Sofue · T. Iga
Orthopaedic Division, Nakajo Central Hospital, Niigata, Japan

T. Matsumoto · T. Sugimori
Department of Orthopaedic Surgery, Kanazawa Medical University, Uchinada, Japan

Y. Hamada
Orthopaedic Division, Mitsuwadai General Hospital, Chiba, Japan

H. Shindo · K. Okano
Department of Orthopaedic Surgery, Graduate School of Medicine, Nagasaki University, Nagasaki, Japan

Y. Takatori
Division of Science for Joint Reconstruction, Graduate School of Medicine, The University of Tokyo, Tokyo, Japan

H. Yamada · K. Ando
Department of Orthopaedic Surgery, Fujita Health University, School of Medicine, Toyoake, Japan

Y. Yasunaga · T. Hamaki
Department of Artificial Joints and Biomaterials, Graduate School of Biomedical Sciences, Hiroshima University, Hiroshima, Japan

H. Ito · T. Hirayama
Department of Orthopaedic Surgery, Asahikawa Medical College, Asahikawa, Japan

S. Mori
Department of Bone and Joint Surgery, Seirei Hamamatsu General Hospital, Hamamatsu, Japan

I. Owan · S. Nakasone
Department of Clinical Neuroscience, Orthopedic Surgery, School of Medicine, University of the Ryukyus, Nishihara, Japan

G. Fujii
Tohoku Hip Joint Center, Matsuda Hospital, Sendai, Japan

H. Ohashi · M. Matsuura
Department of Orthopedic Surgery, Saiseikai Nakatsu Hospital, Osaka, Japan

Y. Iwamoto · T. Mawatari
Department of Orthopaedic Surgery, Clinical Medicine, Graduate School of Medical Sciences, Kyushu University, Fukuoka, Japan

N. Takahira
Department of Rehabilitation, School of Allied Health Sciences, Kitasato University, Sagamihara, Japan

institutions. The acetabular dysplasia indexes were also chosen according to the reproducibility and measured in the radiograph of bilateral hip joints. The clinical score was assessed using the JOA scoring system. The relative risk of the grade of acetabular dysplasia indexes for hip OA was calculated as the odds ratio and the 95% confidence interval.
Results The stage of the OA joints deteriorated with increasing age. The clinical scores also decreased. The grade of the acetabular dysplasia indexes of the OA joints was significantly higher than that of the control joints. Each index of acetabular dysplasia demonstrated significantly increased odds ratios for hip OA. Among the OA joints, the deterioration of the OA stage was found to be significantly associated with an increasing grade of acetabular dysplasia. The odds ratio for OA deterioration in the acetabular dysplasia index was also obtained. The joints of females tended to have a higher grade and prevalence of acetabular dysplasia than those of males.
Conclusions These findings confirmed a high prevalence of acetabular dysplasia in hip OA joints in Japan. Acetabular dysplasia was one of the most important factors associated with hip OA.

Introduction

Osteoarthritis (OA) of the hip is a major disease that affects the healthy life span of a population. It is necessary to understand the patient condition before systematic treatment can be applied. A nationwide epidemiologic study regarding OA of the hip was conducted in Japan and reported previously [1]. This previous study showed the patients with hip OA in Japan to be unique based on the age distribution, the gender heterogeneity, and the disease etiology in comparison to the findings observed in Caucasians. There was a substantially larger number of female than male patients. The peak age of patients at presentation was in the 50s. The etiology was assessed to be acetabular dysplasia in most of the patients. Our study concluded that these unique characteristics of patients in Japan may be related to the occurrence of acetabular dysplasia.

The previous report [1] focused on the data regarding each patient and the current status of patients with hip OA in Japan. This report focused on the data regarding each hip joint, and the involvement of acetabular dysplasia with hip OA was analyzed.

H. Sugiyama
Department of Orthopaedic Surgery, Kanagawa Rehabilitation Hospital, Kanagawa, Japan

T. Karita
Department of Orthopaedic Surgery, Tokyo Metropolitan Tama Medical Center, Tokyo, Japan

K. Iwata
Department of Orthopaedic Surgery, Kagawa University Faculty of Medicine, Miki, Japan

Patients and methods

This study reevaluated the data obtained in a previous multi-institutional examination of patients with hip OA [1]. Data were collected from patients who were newly admitted to the orthopedic outpatient clinic of each institution. Fifteen institutions in five areas of Japan participated in the study. The patients were limited to those old enough to have hip joints that had completed closure of the growth plate. Patients were excluded if they had undergone an operation on both bilateral hip joints after growth plate closure. OA of the hip was defined as a symptomatic hip joint that had radiological evidence of OA changes. A symptomatic hip joint that had a deformity in the joint such as acetabular dysplasia or dislocation, but no OA changes was also included. Data were collected for 9 months after the study had received approval from the institutional review board, including the one at the first author's institution. Written informed consent was obtained from each patient.

Seven hundred twenty OA hips were examined in this study. The data from 65 joints in patients with osteonecrosis of the femoral head (ONFH) and 215 non-OA contralateral joints of the unilateral hip OA patients were collected in the same previous multi-institutional examination as controls. The proportions of female-to-male joints were 90:10, 46:54, and 87:13 in the OA, ONFH, and non-OA groups, respectively. The mean ages of the patients with OA joints, ONFH joints, and non-OA joints were 57.2 ± 14.3 (SD), 48 ± 15.1, and 61.1 ± 13.7 years, respectively.

The stage of hip OA was classified using the system based on the classification proposed by the Japanese Orthopedic Association's (JOA) committee [2] on evaluation criteria for this condition. It was revised according to the reproducibility in the previous preliminary study [3] in order to ensure reliable data from the multiple institutions. It defined four groups of hip OA: the pre-OA stage, the initial stage, the advanced stage, and the terminal stage. Briefly, when a symptomatic hip demonstrated no radiological OA changes but showed morphological changes of the acetabulum and/or proximal femur related to OA, it was assessed as being at pre-OA. The joints that had one or more OA changes and possible narrowing of the joint space were assessed as at the initial stage. An additional condition for the joints at the initial stage was that the width of the joint space was maintained at 2 mm or more throughout the weight-bearing area. The joint was assessed as being at the advanced stage when the width was <2 mm at the thinnest point or loss of joint space was observed, and simultaneously when the width was <15 mm. The joints at the terminal stage showed gross loss of the joint space, and the width was 15 mm or more. Typical radiographs of the OA hip joints at each stage were used for reference to evaluate the stage of the OA joints.

Acetabular dysplasia indexes were also chosen according to the reproducibility for the multi-institutional examination [3] from the Sharp angle [4], the center edge angle [5], the acetabular roof obliquity angle [6], the acetabular head index (AHI) [7], and the approximate acetabular quotient [7]. Sharp angle, acetabular roof obliquity angle, and AHI were assessed as reproducible indexes and were measured in an antero-posterior view radiograph of the bilateral hip joints. The joints at the terminal stage were excluded because the severe OA deformity made measuring difficult.

The clinical score of the hip joints was assessed using the JOA scoring system [8]. The score was based on pain (40 points), range of motion (ROM) (20), gait (20), and ADL (20) scores. The clinical score data regarding pain and ROM were used for assessing each joint in this report. The ROM score was assessed by measuring the flexion and the abduction angle. The pain score was assessed as follows: no pain (40), slight pain just after a long walk (30), moderate pain while walking (20), infrequent resting pain (10), and continuous resting pain (0).

The joint's characteristics, including the clinical score and the stage classification, were compared across age categories or across stage categories, using a Kruskal-Wallis test (continuous variables) and a Mantel-Haenszel chi-square test (categorical variables). The index data of acetabular dysplasia in the hip OA joints were also compared with those in the control joints using a Wilcoxon rank sum test (continuous variables) and a Mantel-Haenszel chi-square test (categorical variables). The relative risk of the grade of acetabular dysplasia indexes for hip OA and the stage of deterioration was calculated as the odds ratio and the 95% confidence interval using logistic regression models and proportional odds models. All analyses were performed using the Statistical Analysis System® version 9.1 software program package (SAS Institute, Cary, NC). Differences with p values of <0.05 were considered to be statistically significant.

Results

The proportion of the OA joints at each stage varied depending on the age generation, although the proportions of OA joints at each stage in the whole group were not significantly different from each other. The OA stage significantly deteriorated with age (Table 1). The clinical scores for pain and ADL of the OA joints also decreased with the increasing age of the joints. Both the pain and ADL scores significantly decreased according to the stage of deterioration (Table 2).

The mean Sharp angle and the mean acetabular roof obliquity angle of the OA joints were significantly larger than that of the ONFH joints or than that of the non-OA joints (Table 3). The mean AHI of the OA joints was significantly lower than that of the ONFH joints or than that of the non-OA joints. A comparison of the proportion of each category in various acetabular indexes revealed that the proportion of the relatively large Sharp angle or acetabular roof obliquity angle was higher in the OA joints than that in the ONFH joints or than that in the non-OA joints. The proportion of the relatively small AHI was higher in the OA joints than that in the ONFH joints or than that in the non-OA joints. Furthermore, the mean acetabular roof obliquity angle of the non-OA joints was significantly larger than that of the ONFH joints. The proportion of the relatively larger acetabular roof obliquity angle was

Table 1 Stage classification and clinical scores of the OA joints

	Total ($N = 720$)	<30 years old ($N = 34$)	30–39 ($N = 50$)	40–49 ($N = 108$)	50–59 ($N = 199$)	60–69 ($N = 161$)	70–79 ($N = 142$)	≥80 ($N = 26$)	p value
Stage [number (%)]									
Pre-OA	167 (23)	22 (65)	31 (62)	33 (31)	40 (20)	25 (16)	15 (11)	1 (4)	<0.0001*
Initial	124 (17)	12 (35)	15 (30)	26 (24)	31 (16)	21 (13)	17 (12)	2 (8)	
Advanced	168 (23)	0 (0)	2 (4)	25 (23)	71 (36)	31 (19)	34 (24)	5 (19)	
Terminal	261 (36)	0 (0)	2 (4)	24 (22)	57 (29)	84 (52)	76 (54)	18 (69)	
Clinical score [mean (SD)]									
Pain	21.3 (12.2)	25.7 (12.1)	29.1 (11.1)	21.6 (12.5)	20.7 (12.1)	19.6 (12.0)	21.0 (11.6)	14.8 (12.0)	<0.0001**
ROM	15.1 (4.8)	18.9 (2.1)	19.0 (2.0)	16.2 (4.4)	14.7 (5.2)	14.3 (4.9)	14.1 (4.7)	12.7 (3.4)	<0.0001**

* Mantel-Haenszel chi-square test

** Kruskal-Wallis test

Table 2 Relationship between the stage and the clinical scores

	Stage				*p* value
	Pre-OA ($N = 167$)	Initial ($N = 124$)	Advanced ($N = 168$)	Terminal ($N = 261$)	
Pain [mean (SD)]	31.2 (10.6)	24.5 (12.4)	17.8 (10.7)	15.6 (9.3)	<0.0001*
ROM [mean (SD)]	19.3 (1.8)	18.2 (2.4)	14.5 (3.8)	11.5 (4.6)	<0.0001*

* Kruskal-Wallis test

Table 3 Indexes of acetabular dysplasia in the OA joints compared with those in the control joints

	OA joints ($N = 407$)	ONFH joints ($N = 61$)	Non-OA joints ($N = 198$)	*p* value (OA vs. ONFH)	*p* value (OA vs. non-OA)	*p* value (ONFH vs. non-OA)
SHARP angle						
Mean (SD)	45.0 (5.1)	39.8 (4.0)	40.6 (5.1)	<0.0001*	<0.0001*	0.089*
<40	54 (13.3)[#]	26 (42.6)	66 (33.3)	<0.0001**	<0.0001**	0.101**
40–44	116 (28.5)	29 (47.5)	99 (50.0)			
45–49	166 (40.8)	6 (9.8)	32 (16.2)			
50+	71 (17.5)	0 (0)	1 (0.5)			
Acetabular roof obliquity angle						
Mean (SD)	20.3 (8.4)	9.9 (6.4)	12.2 (6.0)	<0.0001*	<0.0001*	0.001*
<10	38 (9.3)	35 (57.4)	60 (30.3)	<0.0001**	<0.0001**	0.005**
10–19	153 (37.6)	21 (34.4)	121 (61.1)			
20–29	163 (40.1)	4 (6.6)	16 (8.1)			
30+	53 (13.1)	1 (1.6)	1 (0.5)			
AHI (%)						
Mean (SD)	69.7 (12.0)	83.3 (6.8)	81.1 (8.4)	<0.0001*	<0.0001*	0.076*
80+	78 (19.2)	45 (73.8)	117 (59.1)	<0.0001**	<0.0001**	0.031**
70–79	144 (35.4)	15 (24.6)	71 (35.9)			
60–69	102 (25.1)	1 (1.6)	9 (4.5)			
<60	83 (20.4)	0 (0)	1 (0.5)			

* Wilcoxon rank sum test

** Mantel-Haenszel chi-square test

[#] Percentage in parentheses

higher in the non-OA joints than that in the ONFH joints. The proportion of the relatively smaller AHI was higher in the non-OA joints than in the ONFH joints.

An analysis of the joints of the OA patients including the OA and non-OA joints determined the odds ratio for OA in each index of acetabular dysplasia. Sharp angles of more than 45° or 50° had significantly increased odds ratios of 6- or 87-fold greater for hip OA, respectively, in comparison to the joints in which the Sharp angles were <40° (Table 4). The corresponding age-adjusted ratio was approximately 5- or 65-fold greater, respectively. Either crude odds ratio or the age-adjusted odds ratio increased with an increase of the Sharp angle. The odds ratio of the joints in which the acetabular roof obliquity angle was more than 10°, 20°, or 30° was approximately 2-, 16-, or 84-fold greater, respectively, in comparison to the joints where the angles were <10°. The age-adjusted odds ratio was approximately 2-, 16-, or 83-fold greater, respectively. The association between higher acetabular roof obliquity angle and hip OA was dose respondent in crude and age-adjusted analyses. The odds ratio of the joints in which the AHIs were less than 80, 70, or 60% was approximately 3-, 17-, or 125-fold greater, respectively, in comparison to the joints in which the AHIs were higher than 80%. The age-adjusted odds ratio was approximately 3-, 15-, or 100-fold greater, respectively. Either the odds ratio or the age-adjusted odds ratio increased with a decrease of AHI.

There was a significant relationship between the acetabular roof obliquity angle and the stage of the OA joints (Table 5). The acetabular roof obliquity angle increased according to the stage of deterioration. The AHI also significantly decreased with the stage of deterioration.

Table 4 The relative risk of the grade of acetabular indexes for hip OA

	OA joints ($N = 407$)	Non-OA joints ($N = 198$)	Univariate			Age-adjusted		
			OR	95% CI	p value	OR	95% CI	p value
Sharp angle [number (%)]								
<40	54 (13)	66 (33)	1.00			1.00		
40–44	116 (29)	99 (50)	1.43	0.91–2.24	0.117	1.29	0.82–2.04	0.277
45–49	166 (41)	32 (16)	6.34	3.76–10.7	<0.0001	4.99	2.88–8.66	<0.0001
50+	71 (17)	1 (1)	86.8	11.7–645	<0.0001	65.4	8.70–492	<0.0001
			(Trend $p < 0.0001$)			(Trend $p < 0.0001$)		
Acetabular roof obliquity angle								
<10	38 (9)	60 (30)	1.00			1.00		
10–19	153 (38)	121 (61)	2.00	1.25–3.20	0.004	2.07	1.27–3.38	0.004
20–29	163 (40)	16 (8)	16.1	8.36–31.0	<0.0001	16.2	8.31–31.7	<0.0001
30+	53 (13)	1 (1)	83.6	11.1–630	<0.0001	83.1	11.0–630	<0.0001
			(Trend $p < 0.0001$)			(Trend $p < 0.0001$)		
AHI (%)								
80+	78 (19)	117 (59)	1.00			1.00		
70–79	144 (35)	71 (36)	3.04	2.03–4.56	<0.0001	2.70	1.79–4.08	<0.0001
60–69	102 (25)	9 (5)	17.0	8.12–35.6	<0.0001	14.5	4.88–30.6	<0.0001
<60	83 (20)	1 (1)	125	17.0–913	<0.0001	100	13.6–737	<0.0001
			(Trend $p < 0.0001$)			(Trend $p < 0.0001$)		

However, there was no significant relationship between the Sharp angle and the stage of classification.

An analysis of the OA joints excluding the OA joints at the terminal stage showed the odds ratio for the stage of deterioration in each index of acetabular dysplasia. The odds ratio of the joints in which the angle was more than 20° or 30° was approximately 3- or 15-fold greater, respectively (Table 6), in comparison to the joints in which the acetabular roof obliquity angle was <10°. The age-adjusted odds ratio was approximately 3- or 18-fold greater, respectively. Either the crude odds ratio or the age-adjusted odds ratio increased with an increase of the angle. The odds ratio of the joints in which AHIs were <60 was approximately threefold greater in comparison to the joints in which the AHIs were more than 80. The age-adjusted odds ratio of the joints that were less than 70 or 60 was approximately two- or six-fold greater, respectively. Either the crude odds ratio or the age-adjusted odds ratio increased with a decrease of AHI. The data of the Sharp angle were not statistically significantly associated with the OA deterioration stage.

Comparing the indices of acetabular dysplasia in the joints of females and males, the mean acetabular roof oblique angle was significantly higher in the joints of females than in those of males (Table 7). The mean AHI tended to be lower in the joints of females than in those of males. The proportion of the relatively larger Sharp angle or acetabular roof obliquity angle was higher in the joints of females than in those of males. An analysis of the joints of the female OA patients, including OA and non-OA joints, revealed a significant odds ratio for OA in each index of acetabular dysplasia (Table 8).

Discussion

The analysis of the stage classification for OA joints revealed that the severity of OA joints increased with increasing age. The clinical scores of pain and ROM for the joints also declined with increasing age, and there was a significant relationship between the classification stage and the clinical score. These data indicated that the natural course of OA hip joints generally deteriorated with aging. In addition, the high proportion of OA joints with acetabular dysplasia may strengthen this tendency, as previously reported [1] and as shown in this study. Acetabular dysplasia of the hip joints usually develops prior to early adolescence, and the period that acetabular dysplasia can influence the etiology of hip OA increases with aging.

The OA joints had a statistically significant tendency to have acetabular dysplasia in comparison to the control joints, based on the indexes measured in the hip radiographs. The acetabulum of the ONFH control joints remained intact, and the acetabular dysplasia indexes of the ONFH joints were equivalent to those in the hip joints in the normal population. The significantly high grade of

Table 5 Relationship between the stage of classification and the indexes of acetabular dysplasia in the OA joints

	Pre-OA (*N* = 157)	Initial stage (*N* = 106)	Advanced stage (*N* = 144)	*p* value
SHARP angle				
Mean (SD)	45.1 (4.0)	45.3 (5.6)	44.5 (5.8)	0.435*
<40	16 (10.2)#	13 (12.3)	25 (17.4)	0.361**
40–44.9	47 (29.9)	27 (25.5)	42 (29.2)	
45–49.9	77 (49.0)	41 (38.7)	48 (33.3)	
50–54.9	17 (10.8)	24 (22.6)	28 (19.4)	
55–59.9	0 (0.0)	1 (0.9)	1 (0.7)	
Acetabular roof obliquity angle				
Mean (SD)	17.1 (6.7)	20.0 (7.5)	23.9 (9.2)	<0.0001*
<10	24 (15.3)	8 (7.5)	6 (4.2)	<0.0001**
10–14.9	29 (18.5)	18 (17.0)	14 (9.7)	
15–19.9	46 (29.3)	21 (19.8)	25 (17.4)	
20–24.9	38 (24.2)	26 (24.5)	36 (25.0)	
25–29.9	16 (10.2)	22 (20.8)	25 (17.4)	
30–34.9	3 (1.9)	8 (7.5)	19 (13.2)	
35–39.9	1 (0.6)	3 (2.8)	9 (6.3)	
40+	0 (0)	0 (0.0)	10 (6.9)	
AHI (%)				
Mean (SD)	73.2 (9.4)	69.8 (11.0)	65.9 (14.1)	<0.0001*
<40	0 (0)	0 (0.0)	4 (2.8)	<0.0001**
40–49	0 (0)	3 (2.8)	15 (10.4)	
50–59	16 (10.2)	18 (17.0)	27 (18.8)	
60–69	35 (22.3)	27 (25.5)	40 (27.8)	
70–79	73 (46.5)	34 (32.1)	37 (25.7)	
80–89	26 (16.6)	21 (19.8)	15 (10.4)	
90+	7 (4.5)	3 (2.8)	6 (4.2)	

* Kruskal-Wallis test

** Mantel-Haenszel chi-square test

Percentage in parentheses

acetabular dysplasia of the OA joints in comparison to the ONFH control joints indicated a significantly high proportion of joints with acetabular dysplasia in the OA joints. In contrast, the non-OA joints were in the contralateral joints of the unilateral hip OA patients. These would include the joints that had acetabular dysplasia but had not developed OA yet. The significantly high grade of acetabular dysplasia of the OA joints in comparison to the non-OA joints indicated that the grade of acetabular dysplasia correlated with the incidence of the OA joints. In addition, the non-OA joints tended to have a higher grade of acetabular dysplasia than the ONFH control joints. This suggests that many hip OA patients have acetabular dysplasia in both of the joints, regardless of whether they have OA or non-OA disease. Our previous report [1] clarified that there is a high proportion of bilateral involvement of hip OA, as well as a high proportion of acetabular dysplasia, especially in young patients. These findings suggest that acetabular dysplasia may therefore have a genetic cause, although the details still remain to be elucidated.

The current study indicated that the grade of acetabular dysplasia was related to significant risk for hip OA. The joints that had significant increased odds ratios were those with a Sharp angle of more than 45°, an acetabular roof obliquity angle of more than 10°, and an AHI <80%. The proportions of OA joints with such acetabular dysplasia among all the OA joints were 58, 91, and 81%, respectively. This indicates that most of the OA joints had acetabular dysplasia with a significant risk for the incidence of OA. These proportions are similar to that shown in the previous report based on the etiology study [1]. The proportion of hip OA joints with acetabular dysplasia in the countries other than Japan has been reported to be relatively low. In previous reports from England [9], South Africa [10], and the United States [11], the proportions were 21%, approximately 20%, and more than 40%, respectively. The current study confirmed a high prevalence of acetabular dysplasia in hip OA joints in Japan.

A previous study that examined radiographic and patient factors associated with pre-radiographic OA in hip dysplasia found that OA was associated with increasing age as well as with the severity of dysplasia [12]. Another study using white women aged 65 and above with and without radiographic hip OA did not obtain a statistically

Table 6 The relative risk of the grade of acetabular dysplasia indexes for the stage of deterioration of hip osteoarthritis

	Pre-OA stage ($N = 157$)	Early stage ($N = 106$)	Advanced stage ($N = 144$)	Univariate			Age-adjusted		
				OR	95% CI	p value	OR	95% CI	p value
SHARP angle [number (%)]									
<40	16 (10)	13 (12)	25 (17)	1.00			1.00		
40–44	47 (30)	27 (25)	42 (29)	0.63	0.35–1.15	0.131	0.77	0.41–1.43	0.405
45–49	77 (49)	41 (39)	48 (33)	0.47	0.27–0.84	0.010	0.88	0.47–1.62	0.67
50+	17 (11)	25 (24)	29 (20)	0.98	0.51–1.88	0.940	2.08	1.02–4.26	0.044
				(Trend $p = 0.731$)			(Trend $p = 0.021$)		
Acetabular roof oblique angle									
<10	24 (15)	8 (8)	6 (4)	1.00			1.00		
10–19	75 (48)	39 (37)	39 (27)	1.81	0.89–3.63	0.100	1.64	0.79–3.41	0.185
20–29	54 (34)	48 (45)	61 (42)	3.38	1.67–6.83	0.001	3.41	1.65–7.06	0.001
30+	4 (3)	11 (10)	38 (26)	14.8	6.08–35.8	<0.0001	17.6	6.97–44.3	<0.0001
				(Trend $p < 0.0001$)			(Trend $p < 0.0001$)		
AHI (%)									
80+	33 (21)	24 (23)	21 (15)	1.00			1.00		
70–79	73 (46)	34 (32)	37 (26)	0.79	0.47–1.32	0.368	1.02	0.60–1.75	0.945
60–69	35 (22)	27 (25)	40 (28)	1.54	0.89–2.66	0.120	2.33	1.30–4.15	0.004
<60	16 (10)	21 (20)	46 (32)	3.10	1.72–5.59	0.0002	6.07	3.19–11.6	<0.0001
				(Trend $p < 0.0001$)			(Trend $p < 0.0001$)		

Table 7 A sex difference in the indexes of acetabular dysplasia in the OA joints

	Male ($N = 40$)	Female ($N = 367$)	p value
SHARP angle			
Mean (SD)	43.2 (6.4)	45.1 (4.9)	0.067**
<40	11 (28)[#]	43 (12)	0.048*
40–44	9 (23)	107 (29)	
45–49	15 (38)	151 (41)	
50+	5 (13)	66 (18)	
Acetabular roof obliquity angle			
Mean (SD)	15.5 (8.4)	20.8 (8.2)	0.001**
<10	11 (28)	28 (7)	0.0002*
10–19	15 (38)	138 (38)	
20–29	13 (33)	150 (41)	
30+	1 (3)	52 (14)	
AHI (%)			
Mean (SD)	73.1 (10.7)	69.4 (12.1)	0.051**
80+	11 (28)	67 (18)	0.115*
70–79	15 (38)	129 (35)	
60–69	8 (20)	94 (26)	
<60	6 (15)	77 (21)	

* Mantel-Haenszel chi-square test

** Wilcoxon rank sum test

[#] Percentage in parentheses

significant odds ratio for the incidence of OA [13]. In contrast, a similar study of elderly white women found the odds ratio for the association of abnormal center-edge angle and acetabular dysplasia with incident hip OA to be 3.3 and 2.8, respectively [14]. The current study found a tendency for crude odds ratios for hip OA to be higher than the age-adjusted one. However, the age-adjusted odds ratios using any acetabular dysplasia indexes were high enough to show the involvement of acetabular dysplasia in hip OA. Acetabular dysplasia as well as aging is an important etiology for hip OA caused by abnormal loading and abnormal instability [15].

Some ONFH control joints included those that had sufficient acetabular dysplasia to have a significant risk for OA. The proportions of the ONFH joints with such acetabular dysplasia in all of the ONFH joints were 10, 43, and 26.2%, respectively, according to the grade of Sharp angle, acetabular roof obliquity angle, and AHI. In addition, the proportion of ONFH joints that had a more than ten-fold greater odds ratio for OA according to the grade of the acetabular dysplasia indexes of the acetabular roof obliquity angle and AHI were 8 and 2%, respectively. Therefore, some hip joints with sufficiently severe acetabular dysplasia to be at risk for OA may be included in the normal population. This proportion of hip joints with acetabular dysplasia in the normal population is relatively high com-

Table 8 The relative risk of the grade of acetabular dysplasia indexes for hip OA in the joints of females

	OA joints ($N = 367$)	Non-OA joints ($N = 172$)	Univariate			Age-adjusted		
			OR	95% CI	p value	OR	95% CI	p value
Sharp angle [number (%)]								
<40	43 (12)	55 (32)	1.00			1.00		
40–44	107 (29)	88 (51)	1.56	0.95–2.54	0.077	1.38	0.84–2.27	0.209
45–49	151 (41)	28 (16)	6.90	3.91–12.2	<0.0001	5.20	2.84–9.51	<0.0001
50+	66 (18)	1 (1)	84.4	11.3–633	<0.0001	60.4	7.93–460	<0.0001
			(Trend $p < 0.0001$)			(Trend $p < 0.0001$)		
Acetabular roof obliquity angle								
<10	28 (7)	49 (29)	1.00			1.00		
10–19	138 (38)	106 (62)	2.36	1.39–4.03	0.002	2.55	1.45–4.46	0.001
20–29	150 (41)	16 (9)	17.0	8.47–34.2	<0.0001	17.9	8.69–36.8	<0.0001
30+	52 (14)	1 (1)	94.3	12.3–721	<0.0001	97.1	12.6–750	<0.0001
			(Trend $p < 0.0001$)			(Trend $p < 0.0001$)		
AHI (%)								
80+	67 (18)	103 (60)	1.00			1.00		
70–79	129 (35)	61 (36)	3.25	2.11–5.01	<0.0001	2.86	1.84–4.46	<0.0001
60–69	94 (26)	8 (5)	18.1	8.24–39.6	<0.0001	15.0	6.81–33.2	<0.0001
<60	77 (21)	0 (0)	NA			NA		
			(Trend $p < 0.0001$)			(Trend $p < 0.0001$)		

pared to reports from other countries. In France, the proportion is reported to be approximately one half of that in Japan [16]. The proportions of hip joints with <25° of the center edge angle were 16 and 4% of men in Japan and Britain, respectively [17]. According to the degree of the center edge angle, they were reported to be 3.3, 10.4, and 4.5% in Nigerian [18], Turkish [19], and Chinese men [20], respectively.

Several previous prospective studies showed acetabular dysplasia is associated with a significant risk of hip OA. A prospective cohort study [21] found that hip joints with acetabular dysplasia (the center edge angle <25°) had a 4.3-fold increased risk for OA. A study using non-OA hip joints of the unilateral hip OA patients [22] showed that hips with an abnormal acetabular roof obliquity angle had a significantly increased probability to develop OA (OR 5.96). Although the current study was not prospective, the grade of the odds ratio was consistent with these earlier studies. In addition, there was a significant tendency of an increased odds ratio according to the grade of acetabular dysplasia. At most, the odds ratio was up to approximately 100-fold. Furthermore, the stage classification data revealed that the grade of acetabular dysplasia of the OA joints had a significant relationship with deterioration of OA. The OA joints that had a high grade of acetabular dysplasia had a significant risk for OA deterioration. These data indicated that acetabular dysplasia is one of the most important factors associated with hip OA.

The joints of females tended to have a higher grade and prevalence of acetabular dysplasia than the joints of males. The etiology study in the previous report also showed that acetabular dysplasia is present in more than 80% of female patients in contrast to approximately half of the male patients [1]. The estrogen receptor genotype is involved in the prevalence of hip OA [23]. Therefore, the sex difference in the involvement of acetabular dysplasia may also depend on genetic differences. The relative risk of the grade of acetabular dysplasia indices for hip OA in the female joints was similar to that in all joints. This is because of the high percentage of female joints in all of the OA hip joints in our study and the high prevalence of acetabular dysplasia in the joints of females. An analysis limited to the joints of females confirmed the involvement of acetabular dysplasia in hip OA.

Although the prevalence of normal control joints in the ONFH joints was indicated in the current study, the correct prevalence of hip OA in the normal population was not shown. Although the relative risk for OA depending on the grade of acetabular dysplasia was shown in the current study, the relative risk for OA incidence was not indicated, since it was not a cohort study. This nationwide and multi-institutional epidemiological study showed the existence of both a high grade and prevalence of acetabular dysplasia in Japan, especially in the joints of females, and acetabular dysplasia is therefore considered to be closely involved with hip OA.

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