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Respective association of joint space narrowing and osteophyte formation with knee symptoms and function in China

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Abstract

Background Joint space narrowing (JSN) and osteophytes are rarely studied separately regarding their risk factors and impacts on knee symptoms and function, particularly in the Chinese population.

Methods This study utilized data from the Shunyi Osteoarthritis Study. Residents over 50 years old were randomly selected and completed a home interview questionnaire. Clinical assessments included measurements of height, weight, range of motion (ROM), a chair stand test, and a 50-foot walk test. Radiographs of the tibiofemoral joints were taken in a semi-flexed, weight-bearing position, and medial JSN and osteophytes grades were recorded (grades 0 to 3). Univariate analyses were used to screen variables, and multivariate analyses were conducted to investigate the respective risk factors for JSN and osteophytes, as well as their impacts on knee symptoms and function.

Results A total of 1,184 patients (795 females and 389 males; mean age 61.1 ± 7.4 years) were enrolled in this study. Multiple regression analysis revealed that older females with history of knee injury were significantly more likely to exhibit JSN and osteophytes on radiographs. JSN was associated with slower gait speed and increased knee pain. Tibial osteophytes were linked to reduced performance in the chair stand test, while femoral osteophytes were correlated with gait speed and lower SF-12 physical component summary scores. All these factors contributed to reduced ROM.

Conclusion This study found that JSN and osteophytes had different impacts on function and symptoms in KOA. However, no differences in risk factors were observed between JSN and osteophytes.

Keywords Knee osteoarthritis, Joint space narrowing, Osteophyte, Symptom, Function

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Introduction

Knee osteoarthritis (KOA) is a major public health issue causing chronic disability in the elderly [1, 2]. As a rapidly aging society with growing senior population, China's prevalence of KOA among the elderly is high [3], and the medical burden of KOA has increased by years.

Previous studies have identified the radiographic features of KOA, including joint space narrowing (JSN) and osteophytes, which are major elements of the Kellgren-Lawrence (KL) grade. Many studies have explored the risk factors associated with radiographic features and their impact on knee symptoms and function [4–6]. However, most of these studies rely on the KL grade, a categorical system that does not separately assess JSN and osteophytes. The distinctions between JSN and osteophytes in the progression of KOA, the differing risk factors for these features, and their specific impacts on knee symptoms and function remain insufficiently understood.

Few studies have explored the differences between risk factors for JSN and osteophytes. In Road study, Muraki [7] found that, among women, vitamins K, B1, B2, B6, C were associated with minimum joint space width value, and vitamins E, K, B1, B2, niacin, B6 were significantly associated with the size of osteophyte area. Further research from the Road study showed that kneeling, squatting, walking, and heavy lifting were associated with minimum joint space width. For the size of osteophyte area, time spent on kneeling and squatting were significantly associated with larger area, whereas other activities showed no such association [8]. As for symptoms, limited studies have been reported. In Road study, referring to the WOMAC scores, Muraki [9] specified that minimum joint space width was significantly associated with score on the pain, while osteophyte area was significantly associated with score on the physical function for both men and women. Another study conducted by Neogi showed that both JSN and osteophytes were associated with frequent knee pain, consistency of frequent knee pain, and severity of knee pain. Furthermore, JSN was more strongly associated with each pain measure than were osteophytes [10].

These accumulating evidences have indicated that JSN and osteophytes may have distinct etiologic mechanisms and their progression may be neither constant nor proportional. Thus, to examine risk factors and outcomes associated with KOA, these two features should be assessed separately.

However, to date, there is a paucity of literature comparing the impact of JSN and osteophytes on knee function, particularly based on physical test. To the best of our knowledge, no large population-based studies have investigated the differences in risk factors and outcomes between JSN and osteophytes in China. This study aimed to explore the risk factors of JSN and osteophytes separately, and clarify their respective impacts on knee symptoms and function.

Method

Study design and participants

The Beijing Shunyi Osteoarthritis Study was a population-based, longitudinal, and prospective study of knee osteoarthritis, approved by the Ethics Committee of Peking University People's Hospital (2013-Z-24, 2018PHB166-01). The study was based on a random cluster sampling method in 2014 [3]. Fourteen villages in Shunyi District, Beijing, China, were involved, and every resident who participated in the survey had signed the informed consent document.

The inclusion criteria for this study were: (1) residence in Shunyi District, Beijing, and (2) age over 50 years. Exclusion criteria: (1) rheumatoid arthritis, (2) physical disability, (3) mental retardation, (4) advanced malignant tumors or bedridden, (5) living or working outside for the last 6 months or above, (6) failed to complete the main records, and (7) obviously uncooperative during the survey.

At the time of each visit, participants completed a home interview questionnaire and underwent a clinical examination including measurements of height, weight, range of motion, chair stand test, 50-foot walk test. Weight-bearing posterior-anterior semi-flexed radiographs of the tibiofemoral joints were obtained and were read using the OARSI atlas.

Our questionnaire and radiograph techniques were based on the Beijing OA study [11] and has been validated through its use in surveys conducted in other regions [12].

Assessment of radiographic osteoarthritis

Radiographs were assessed following previous studies [13, 14]. Joint space narrow, tibial and femoral osteophytes were all divided into four categories (0–3) and were recorded separately. Radiographs were read twice by two readers trained at Boston University, and films from Osteoarthritis Initiatives were used as the standard as well as reader's training material [11]. For each batch of Shunyi OA Study films ($n = 100$), 10 films from the Osteoarthritis Initiatives study were included to test inter-reader reliability. In addition, 10 previously read knee radiographs from the Shunyi OA Study were fed back to the reader to test intra-reader reliability. Weighted kappa statistics for inter-reader and intra-reader reliability were 0.82 and 0.95 respectively.

Assessment of covariates

Demographic information, such as age, sex, education level, history of knee injury and occupational activity,

was collected at baseline using a standard questionnaire. History of knee injury was identified by asking subjects "Have you ever suffered an injury in your knees causing a limitation of walking ability for at least one week?" Information collected about job title and occupational activity included a lifetime occupational history with details of seven types of specific workplace physical activities: walking, bumpy road walking, bicycling, standing, digging, kneeling, squatting, climbing, heavy lifting, and bending knee.

Participants were asked whether they were engaged in the following activities: walking on flat or bumpy road for 2 h/day, bicycling for 2 h/day, standing for 2 h/day, digging for 2 h/day, kneeling for 0.5 h/day, squatting for 0.5 h/day, climbing stairs more than 10 steps/day, lifting loads weighing 10 kg 1 time/day, and bending knee for 2 h/day. Information on above activities was obtained for the principal job, defined as the job at which the participant had worked longest.

Height was measured twice for each subject, using a wall-mounted stadiometer. Weight was assessed using a balance beam scale with a precision to 0.1 kg. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared. Range of motion (ROM) was assessed by goniometric measurement. A chair stand test was carried out using a 43 cm high, straight back armless chair. For repeated chair stands, the participants were asked to fold their arms across their chests and to stand up and sit down five times as quickly as possible, and researcher measured participant's the length of time required [15]. A 50-foot walk test was carried out by asking the participants to walk on a 25-foot straight footpath and return back to the starting point as fast as possible. Total time of the walk was taken twice, and the time of the faster one was used for calculating [16].

Finally, knee pain was assessed using the visual analogue scale (VAS). The SF-12 scores were used to measure the quality of life and acquired by questionnaire and further calculated into the physical component summary (PCS) and mental component summary (MCS) [17, 18].

Statistical analysis

Participants with only medial compartment KOA were included in this study, and a knee with narrower joint space and more serious osteophytes was defined as the designated knee of a participant, and was included in further research [8].

Continuous variables, such as age, walk speed, chair stand test time, ROM, were presented as means ± standard deviation (SD). As for categorical variables, education was categorized in to 3 groups (elementary school below, middle school, high school or higher), while PCS and MCS were each categorized in to 2 groups (below 50, above 50) [19, 20].

T-test and chi-squared test were used for univariate analysis to screen variables. Ordinal logistic regression with a stepwise method was applied to identify the risk factors for JSN and tibial, femoral osteophytes separately. Stepwise linear regression, logistic regression or ordinal logistic regression was used to compare the different effects of JSN and osteophyts on physical function (ROM, walk speed, chair stand) and symptoms (SF-12 scores, pain). Results were presented in the form of odds ratio (OR) or coefficient (COEF) and corresponding 95% confidence interval (CI). All data analysis was performed using R (version 4.3.2). A two-sided P-value less than 0.05 was considered statistically significant, and less than 0.01 was considered highly significant.

Result

Cohort characteristics

A total of 1184 patients were enrolled in this study, with an average age of 61.1 ± 7.4 years old, an average BMI of 26.2 ± 3.6, among which 67.1% were female. The education level of most patients was junior middle school (67.7%). Besides, only 7.3% patients have experienced trauma to at least one knee joint. More demographic information was shown in Table 1.

As for physical function and symptoms, the mean walk speed was 1.2 ± 0.2 m/s. The mean time of chairstand test was 8.8 ± 2.6 s while the mean ROM was 127.6 ± 9.0 degree. More than half of the patients had a high risk of PCS (59.3%), and 37.5% patients had a high risk of MCS. 12.3% patients suffered from knee pain (VAS > 0, 12.3%). (Table 3)

Risk factors for JSN, tibial and femoral osteophytes

Ordinal logistic regressions and further stepwise regressions showed that age, gender, BMI, and a history of knee injury were risk factors for JSN, tibial and femoral osteophytes formation. Elderly patients, females, and those with history of knee joint injury were more likely to have more severe joint space narrowing and osteophytes on radiograph, significantly. However, no relation was found between occupational activities and JSN or osteophytes, and no differences in risk factors were observed between JSN and osteophytes. (More details see Table 2)

Pain and radiograph changes

In the univariate analysis, JSN, tibial and femoral osteophytes were all associated with pain measured by VAS score. After adjusted with gender, age, education, and BMI, stepwise ordinal logistic regression showed that only JSN was associated with higher VAS score.

Table 1 Cohort characteristics

Overall	Number	1184
Age	Mean (SD)	61.1 (7.4)
Gender	Male(%)	389(32.9)
	Female(%)	795 (67.1)
Education	Primary school and below(%)	240 (20.3)
	Junior middle school(%)	802 (67.7)
	High school and above(%)	142 (12.0)
Knee injury history	No(%)	1098(92.7)
	Yes(%)	86 (7.3)
Walking>2h	No(%)	625(52.8)
	Yes(%)	559 (47.2)
Bumpy road walking>2h	No(%)	895(75.6)
	Yes(%)	289 (24.4)
Bicycling>2h	No(%)	1103(93.2)
	Yes(%)	81 (6.8)
Standing>2h	No(%)	543(45.9)
	Yes(%)	641 (54.1)
Digging>2h	No(%)	1012(85.5)
	Yes(%)	172 (14.5)
Kneeling>30min	No(%)	1134(95.8)
	Yes(%)	50 (4.2)
Squating>30min	No(%)	1002(84.6)
	Yes(%)	182 (15.4)
Climbing stairs>10 steps	No(%)	1149(97.0)
	Yes(%)	35 (3.0)
lifting loads weighing>10kg	No(%)	1038(87.7)
	Yes(%)	146 (12.3)
Bending knee>2h	No(%)	999(84.4)
	Yes(%)	185 (15.6)
BMI	mean (SD)	26.2 (3.6)
Femoral osteophyte	Grade 0(%)	823 (69.5)
	Grade 1(%)	192 (16.2)
	Grade 2(%)	125 (10.6)
	Grade 3(%)	44 (3.7)
Tibial osteophyte	Grade 0(%)	638 (53.9)
	Grade 1(%)	427 (36.1)
	Grade 2(%)	101 (8.5)
	Grade 3(%)	18 (1.5)
Joint space narrowing	Grade 0(%)	866 (73.1)
	Grade 1(%)	137 (11.6)
	Grade 2(%)	146 (12.3)
	Grade 3(%)	35 (3.0)

Compared with knee with JSN grade of 0, the odds ratios for VAS score were 1.85 (95%CI:1.08–3.06), 2.40 (95%CI:1.48–3.84), and 5.04 (95%CI:2.36–10.38), for knees with JSN grade of 1, 2, 3, respectively. (More details see Tables 3 and 4)

Quality of life (SF-12) and radiograph changes

In the univariate analysis, JSN, tibial and femoral osteophytes were all associated only with PCS but not MCS. After adjusted with gender, age, education, and BMI, stepwise logistic regressions showed that only femoral osteophytes were associated with PCS. Severe femoral osteophytes were associated with an increased risk of reduced physical quality of life. (grade 3 OR = 3.05 95%CI = 1.35–8.21 $p = 0.014$) None radiograph changes was found associated with MCS. (Tables 3 and 4)

Knee physical function and radiograph changes

ROM

In the univariate analysis, JSN, tibial and femoral osteophytes were all associated with ROM. After adjusting for gender, age, education, and BMI, stepwise linear regression revealed that higher levels of JSN, tibial osteophytes, and femoral osteophytes were all associated with reduced ROM. (More details see Tables 3 and 4)

Walk speed

In the univariate analysis, JSN, tibial and femoral osteophytes were all associated with walk speed. After adjusted with gender, age, education, and BMI, stepwise linear regression showed that higher level of femoral osteophytes (grade 2:OR = 0.943 95%CI = 0.892–0.997 $p = 0.038$, grade 3:OR = 0.871 95%CI = 0.800-0.948 $p < 0.01$) and JSN (grade 3 OR = 0.90 95%CI = 0.82–0.99, $p = 0.028$) were associated with slower walk speed. (More details see Tables 3 and 4)

Chairstand test

In the univariate analysis, JSN, tibial and femoral osteophytes were all associated with walk speed. After adjusted with gender, age, education, and BMI, stepwise linear regression showed that only severe tibial osteophytes (grade 3 OR = 6.10 95%CI = 1.91–19.48, $p = 0.002$) were associated with Chair stand. Patients with severe tibial osteophytes tend to spend more time finishing chairstand test. (Tables 3 and 4)

Discussion

This is the first study to conduct separate examination on the association of joint space narrowing and osteophytes with physical function (ROM, walking speed, chair stand) and symptoms (SF-12 scores, pain) in China. Our study revealed that age, gender, BMI, and a history of knee trauma were risk factors for JSN, tibial and femoral osteophytes formation. JSN was associated with gait speed, knee pain, and ROM. For femoral osteophyte, its formation was correlated with gait speed, SF-12 physical component summary scores, and ROM. As for tibial osteophyte, its occurrence may affect ROM and the performance in the chair-stand test.

The risk factors for KOA have garnered extensive research attention, with age, gender, BMI, and a history of knee trauma widely acknowledged as significant risk factors [21]. However, further exploration of the risk factors associated with joint space narrowing and osteophyte formation remains limited. Our study revealed that age, gender, BMI, and a history of knee trauma were also risk factors for JSN, tibial and femoral osteophyte formation. Among Caucasians, evidence suggested that KOA was more prevalent among those with history of heavy physical labour, particularly for those with occupations

Table 2 Risk factors for radiograph features

	Femoral osteophyte				Tibial osteophyte				JSN			
	OR	95%CI		p value	OR	95%CI		p value	OR	95%CI		p value
Male	-	-	-	-	-	-	-	-	-	-	-	-
Female	4.99	3.55	7.12	<0.01	3.18	2.41	4.23	<0.01	2.33	1.70	3.23	<0.01
Primary school and below	-	-	-	-	-	-	-	-	-	-	-	-
Junior middle school	0.96	0.69	1.33	0.81	1.05	0.77	1.43	0.76	1.07	0.76	1.51	0.70
High school and above	0.70	0.40	1.20	0.21	0.70	0.43	1.14	0.16	0.88	0.49	1.56	0.67
Age	1.11	1.08	1.13	<0.01	1.10	1.08	1.13	<0.01	1.11	1.09	1.14	<0.01
BMI	1.14	1.10	1.18	<0.01	1.10	1.07	1.14	<0.01	1.15	1.11	1.20	<0.01
Knee injury history(No)	-	-	-	-	-	-	-	-	-	-	-	-
Knee injury history(Yes)	2.81	1.81	4.33	<0.01	2.49	1.61	3.84	<0.01	2.96	1.90	4.59	<0.01
Walking>2h(No)	-	-	-	-	-	-	-	-	-	-	-	-
Walking>2h(Yes)	1.08	0.76	1.54	0.67	1.04	0.75	1.43	0.82	0.89	0.62	1.29	0.55
Bumpy road walking>2h(No)	-	-	-	-	-	-	-	-	-	-	-	-
Bumpy road walking>2h(Yes)	0.83	0.57	1.22	0.35	1.30	0.93	1.82	0.13	0.97	0.65	1.43	0.87
Bicycling>2h(No)	-	-	-	-	-	-	-	-	-	-	-	-
Bicycling>2h(Yes)	0.86	0.49	1.48	0.61	0.69	0.42	1.13	0.14	1.08	0.61	1.84	0.78
Standing>2h(No)	-	-	-	-	-	-	-	-	-	-	-	-
Standing>2h(Yes)	0.85	0.60	1.21	0.38	0.88	0.65	1.21	0.44	0.96	0.67	1.38	0.82
Digging>2h(No)	-	-	-	-	-	-	-	-	-	-	-	-
Digging>2h(Yes)	1.46	0.95	2.21	0.08	1.15	0.79	1.68	0.46	1.34	0.86	2.07	0.19
Kneeling>30min(No)	-	-	-	-	-	-	-	-	-	-	-	-
Kneeling>30min(Yes)	1.23	0.57	2.56	0.59	1.32	0.68	2.52	0.41	1.60	0.75	3.33	0.21
Squating>30min(No)	-	-	-	-	-	-	-	-	-	-	-	-
Squating>30min(Yes)	0.78	0.48	1.24	0.30	1.16	0.77	1.73	0.49	0.89	0.54	1.45	0.65
Climbing stairs>10 steps(No)	-	-	-	-	-	-	-	-	-	-	-	-
Climbing stairs>10 steps(Yes)	1.61	0.77	3.22	0.19	1.22	0.60	2.42	0.57	1.38	0.63	2.88	0.41
lifting loads weighing>10kg(No)	-	-	-	-	-	-	-	-	-	-	-	-
lifting loads weighing>10kg(Yes)	0.92	0.54	1.56	0.77	1.13	0.71	1.78	0.60	0.80	0.45	1.39	0.43
Bending knee>2h(No)	-	-	-	-	-	-	-	-	-	-	-	-
Bending knee>2h(Yes)	1.58	0.98	2.54	0.06	0.97	0.63	1.50	0.90	1.30	0.78	2.14	0.31
	value	std.error	t value	p value	value	std.error	t value	p value	value	std.error	t value	p value
0|1	11.58	0.99	11.71	<0.01	9.71	0.89	10.96	<0.01	12.05	1.03	11.70	<0.01
1|2	12.74	1.00	12.71	<0.01	12.07	0.91	13.20	<0.01	12.88	1.04	12.39	<0.01
2|3	14.36	1.03	14.01	<0.01	14.17	0.95	14.91	<0.01	14.83	1.07	13.90	<0.01
Stepwise regressions												
	Femoral osteophyte				Tibial osteophyte				JSN			
	OR	95%CI		p value	OR	95%CI		p value	OR	95%CI		p value
Male	-	-	-	-	-	-	-	-	-	-	-	-
Female	5.00	3.58	7.10	<0.01	3.11	2.37	4.10	<0.01	2.27	1.66	3.12	<0.01
Age	1.11	1.09	1.13	<0.01	1.11	1.09	1.13	<0.01	1.11	1.09	1.13	<0.01
BMI	1.14	1.10	1.18	<0.01	1.10	1.07	1.14	<0.01	1.15	1.11	1.20	<0.01
Knee injury history(No)	-	-	-	-	-	-	-	-	-	-	-	-
Knee injury history(Yes)	2.83	1.83	4.36	<0.01	2.47	1.60	3.81	<0.01	2.97	1.92	4.58	<0.01
Bumpy road walking>2h(No)	-	-	-	-	-	-	-	-				
Bumpy road walking>2h(Yes)	0.77	0.56	1.06	0.11	1.24	0.94	1.64	0.12				
Bicycling>2h(No)					-	-	-	-				
Bicycling>2h(Yes)					0.70	0.43	1.14	0.16				
Digging>2h(No)	-	-	-	-								
Digging>2h(Yes)	1.37	0.92	2.00	0.11								
Kneeling>30min(No)					-	-	-	-	-	-	-	-
Kneeling>30min(Yes)					1.72	0.99	2.95	0.05	1.68	0.90	3.03	0.09
Bending knee>2h(No)	-	-	-	-								
Bending knee>2h(Yes)	1.39	0.95	2.01	0.08								
	value	std.error	t value	p value	value	std.error	t value	p value	value	std.error	t value	p value
0|1	12.01	0.91	13.22	<0.01	9.84	0.80	12.31	<0.01	12.10	0.94	12.90	<0.01
1|2	13.17	0.92	14.25	<0.01	12.18	0.83	14.67	<0.01	12.93	0.95	13.63	<0.01
2|3	14.79	0.95	15.60	<0.01	14.28	0.87	16.42	<0.01	14.88	0.98	15.21	<0.01

Table 3 Symptoms and physical function for participants

	Overall	Femoral osteophyte					Tibial osteophyte					JSN				
		0	1	2	3	p value	0	1	2	3	p value	0	1	2	3	p value
Number	1184	823	192	125	44		638	427	101	18		866	137	146	35	
Walk speed (mean (SD))	1.2 (0.24)	1.23 (0.23)	1.18 (0.22)	1.07 (0.20)	0.94 (0.27)	<0.01	1.24 (0.23)	1.17 (0.23)	1.08 (0.24)	0.84 (0.21)	<0.01	1.22 (0.23)	1.20 (0.22)	1.08 (0.23)	0.93 (0.22)	<0.01
Chairstand test time (mean (SD))	8.75 (2.57)	8.55 (2.65)	8.90 (2.12)	9.43 (2.25)	9.89 (2.89)	<0.01	8.60 (2.77)	8.77 (2.20)	9.12 (2.26)	11.40 (3.20)	<0.01	8.59 (2.62)	8.75 (2.17)	9.37 (2.47)	10.15 (2.23)	<0.01
SF-12 PCS						<0.01					<0.01					<0.01
>50(%)	702 (59.3)	459 (55.8)	117 (60.9)	88 (70.4)	38 (86.4)		347 (54.4)	266 (62.3)	73 (72.3)	16 (88.9)		489 (56.5)	86 (62.8)	99 (67.8)	28 (80.0)	
<=50(%)	482(40.7)	364(44.2)	75(39.1)	37(29.6)	6(13.6)		291(45.6)	161(37.7)	28(27.7)	2 (11.1)		377(43.5)	51(37.2)	47(32.2)	7(20.0)	
SF-12 MCS						0.466					0.061					0.111
>50(%)	444 (37.5)	298 (36.2)	75 (39.1)	51 (40.8)	20 (45.5)		223 (35.0)	168 (39.3)	42 (41.6)	11 (61.1)		309 (35.7)	63 (46.0)	57 (39.0)	15 (42.9)	
<=50(%)	740(62.5)	525(63.8)	117(60.9)	74(59.2)	24(54.5)		415(65.0)	259(60.7)	59(58.4)	7(38.9)		557(64.3)	74(54.0)	89(61.0)	20(57.1)	
ROM (mean (SD))	127.6 (9.04)	129.57 (6.56)	126.15 (7.88)	122.95 (9.14)	110.64 (21.62)	<0.01	129.80 (6.58)	126.85 (7.48)	121.27 (11.12)	103.50 (29.66)	<0.01	129.24 (6.79)	126.69 (7.69)	123.18 (10.23)	109.20 (21.89)	<0.01
VAS (%)						<0.01					<0.01					<0.01
0	1038 (87.7)	757 (92.0)	159 (82.8)	94 (75.2)	28 (63.6)		590 (92.5)	365 (85.5)	71 (70.3)	12 (66.7)		792 (91.5)	114 (83.2)	111 (76.0)	21 (60.0)	
1	11 (0.9)	6 (0.7)	3 (1.6)	1 (0.8)	1 (2.3)		6 (0.9)	4 (0.9)	1 (1.0)	0 (0.0)		7 (0.8)	1 (0.7)	3 (2.1)	0 (0.0)	
2	9 (0.8)	5 (0.6)	3 (1.6)	0 (0.0)	1 (2.3)		3 (0.5)	4 (0.9)	2 (2.0)	0 (0.0)		6 (0.7)	1 (0.7)	2 (1.4)	0 (0.0)	
3	23 (1.9)	13 (1.6)	4 (2.1)	3 (2.4)	3 (6.8)		7 (1.1)	8 (1.9)	8 (7.9)	0 (0.0)		13 (1.5)	3 (2.2)	4 (2.7)	3 (8.6)	
4	19 (1.6)	8 (1.0)	4 (2.1)	4 (3.2)	3 (6.8)		7 (1.1)	7 (1.6)	3 (3.0)	2 (11.1)		11 (1.3)	0 (0.0)	7 (4.8)	1 (2.9)	
5	30 (2.5)	13 (1.6)	5 (2.6)	8 (6.4)	4 (9.1)		9 (1.4)	14 (3.3)	7 (6.9)	0 (0.0)		12 (1.4)	8 (5.8)	7 (4.8)	3 (8.6)	
6	15 (1.3)	6 (0.7)	4 (2.1)	4 (3.2)	1 (2.3)		4 (0.6)	7 (1.6)	2 (2.0)	2 (11.1)		7 (0.8)	3 (2.2)	4 (2.7)	1 (2.9)	
7	19 (1.6)	6 (0.7)	6 (3.1)	6 (4.8)	1 (2.3)		5 (0.8)	10 (2.3)	3 (3.0)	1 (5.6)		10 (1.2)	3 (2.2)	2 (1.4)	4 (11.4)	
8	11 (0.9)	5 (0.6)	2 (1.0)	3 (2.4)	1 (2.3)		3 (0.5)	5 (1.2)	2 (2.0)	1 (5.6)		4 (0.5)	4 (2.9)	3 (2.1)	0 (0.0)	
9	6 (0.5)	3 (0.4)	1 (0.5)	2 (1.6)	0 (0.0)		3 (0.5)	3 (0.7)	0 (0.0)	0 (0.0)		3 (0.3)	0 (0.0)	2 (1.4)	1 (2.9)	
10	3 (0.3)	1 (0.1)	1 (0.5)	0 (0.0)	1 (2.3)		1 (0.2)	0 (0.0)	2 (2.0)	0 (0.0)		1 (0.1)	0 (0.0)	1 (0.7)	1 (2.9)	

Table 4 Association between knee symptoms, function and radiograph features

	SF-12 PCS				SF-12 MCS				Walk speed			
	OR	95%CI		p value	OR	95%CI		p value	COEF	95%CI		p value
Male	-	-	-	-	-	-	-	-	-	-	-	-
Female	1.95	1.49	2.58	<0.01	1.37	1.04	1.81	0.03	0.92	0.90	0.95	<0.01
Age	1.06	1.04	1.08	<0.01	1.04	1.02	1.06	<0.01	0.99	0.99	0.99	<0.01
Primary school and below	-	-	-	-	-	-	-	-	-	-	-	-
Junior middle school	1.27	0.91	1.76	0.16	1.14	0.83	1.58	0.42	1.04	1.01	1.07	0.02
High school and above	1.49	0.93	2.40	0.10	1.96	1.23	3.14	<0.01	1.03	0.98	1.08	0.25
BMI	0.99	0.96	1.03	0.62	0.98	0.95	1.02	0.35	1.00	0.99	1.04	0.60
Femoral OST 0	-	-	-	-	-	-	-	-	-	-	-	-
Femoral OST 1	0.97	0.66	1.44	0.89	0.92	0.63	1.36	0.69	0.99	0.95	1.03	0.64
Femoral OST 2	1.41	0.78	2.59	0.26	0.97	0.55	1.72	0.93	0.94	0.89	0.99	0.04
Femoral OST 3	3.17	1.06	10.90	<0.05	0.84	0.32	2.15	0.72	0.89	0.81	0.98	<0.05
JSN 0	-	-	-	-	-	-	-	-	-	-	-	-
JSN 1	1.04	0.68	1.59	0.87	1.46	0.97	2.21	0.07	1.02	0.98	1.06	0.42
JSN 2	0.76	0.44	1.31	0.32	0.88	0.51	1.49	0.63	0.99	0.94	1.05	0.83
JSN 3	1.02	0.35	3.15	0.97	0.80	0.30	2.06	0.64	0.91	0.83	1.00	0.06
Tibial OST 0	-	-	-	-	-	-	-	-	-	-	-	-
Tibial OST 1	1.12	0.82	1.52	0.48	1.11	0.82	1.51	0.49	0.99	0.96	1.02	0.38
Tibial OST 2	1.10	0.59	2.08	0.76	1.24	0.68	2.24	0.48	1.01	0.95	1.08	0.71
Tibial OST 3	1.42	0.27	10.99	0.70	3.17	0.87	12.29	0.08	0.91	0.80	1.04	0.19
Stepwise regressions												
	SF-12 PCS				SF-12 MCS				Walk speed			
	OR	95%CI		p value	OR	95%CI		p value	COEF	95%CI		p value
Male	-	-	-	-	-	-	-	-	-	-	-	-
Female	1.92	1.47	2.52	<0.01	1.42	1.09	1.85	<0.01	0.92	0.90	0.95	<0.01
Age	1.06	1.04	1.08	<0.01	1.04	1.02	1.06	<0.01	0.98	0.98	0.99	<0.01
Primary school and below					-	-	-	-	-	-	-	-
Junior middle school					1.15	0.84	1.59	0.39	1.04	1.01	1.07	<0.05
High school and above					1.94	1.22	3.08	<0.01	1.03	0.98	1.08	0.24
Femoral OST 0	-	-	-	-					-	-	-	-
Femoral OST 1	0.96	0.69	1.35	0.82					0.99	0.95	1.03	0.51
Femoral OST 2	1.27	0.83	1.97	0.27					0.94	0.89	1.00	<0.05
Femoral OST 3	3.05	1.35	8.21	<0.01					0.87	0.80	0.95	<0.01
JSN 0									-	-	-	-
JSN 1									1.02	0.97	1.06	0.46
JSN 2									0.99	0.94	1.05	0.83
JSN 3									0.90	0.82	0.99	<0.05

	VAS				Chairstand test				ROM			
	OR	95%CI		p value	COEF	95%CI		p value	COEF	95%CI		p value
Male	-	-	-	-	-	-	-	-	-	-	-	-
Female	1.91	1.21	3.11	<0.01	0.80	0.58	1.10	0.18	0.34	0.13	0.88	0.03
Age	1.02	0.99	1.05	0.19	1.10	1.08	1.12	<0.01	0.95	0.89	1.02	0.14
Primary school and below	-	-	-	-	-	-	-	-	-	-	-	-
Junior middle school	0.70	0.46	1.09	0.11	0.81	0.55	1.17	0.26	4.07	1.33	12.50	<0.01
High school and above	0.54	0.25	1.13	0.12	0.71	0.41	1.24	0.23	3.27	0.63	16.86	0.16
BMI	1.06	1.01	1.11	<0.05	1.03	0.99	1.07	0.19	0.42	0.37	0.47	<0.01
Femoral OST 0	-	-	-	-	-	-	-	-	-	-	-	-
Femoral OST 1	1.37	0.75	2.44	0.30	0.95	0.58	1.54	0.82	1.54	0.36	6.65	0.56
Femoral OST 2	1.50	0.75	2.96	0.25	1.05	0.56	1.96	0.88	0.89	0.14	5.74	0.90
Femoral OST 3	2.75	0.95	7.85	0.06	1.28	0.42	3.92	0.67	4.9E-4	1.7E-5	0.01	<0.01
JSN 0	-	-	-	-	-	-	-	-	-	-	-	-
JSN 1	1.22	0.74	1.99	0.42	0.74	0.51	1.05	0.09	0.36	0.12	1.06	0.06
JSN 2	1.50	0.69	3.21	0.30	0.54	0.27	1.08	0.08	0.09	0.01	0.77	<0.05
JSN 3	1.03	0.24	4.17	0.96	4.24	0.91	19.76	0.07	2.1E-5	2.0E-7	2.0E-3	<0.01
Tibial OST 0	-	-	-	-	-	-	-	-	-	-	-	-
Tibial OST 1	1.39	0.80	2.38	0.24	1.48	0.94	2.33	0.09	0.32	0.08	1.24	0.10
Tibial OST 2	1.53	0.73	3.19	0.26	1.82	0.93	3.57	0.08	0.08	0.01	0.59	<0.01
Tibial OST 3	1.73	0.61	4.76	0.30	1.41	0.46	4.30	0.55	3.3E-4	1.9E-5	0.01	<0.01
Stepwise regressions												
	VAS				Chairstand test				ROM			
	OR	95%CI		p value	COEF	95%CI		p value	COEF	95%CI		p value
Male	-	-	-	-	-	-	-	-				
Female	2.20	1.42	3.51	<0.01	1.11	1.09	1.13	<0.01	No difference			
Age	1.03	1.01	1.06	<0.01	1.03	0.99	1.07	0.10				
BMI	1.06	1.01	1.11	<0.05								
JSN 0	-	-	-	-								
JSN 1	1.85	1.08	3.06	<0.05								
JSN 2	2.40	1.48	3.84	<0.01								
JSN 3	5.04	2.36	10.38	<0.01								
Tibial OST 0					-	-	-	-				
Tibial OST 1					0.87	0.64	1.17	0.35				
Tibial OST 2					0.80	0.47	1.37	0.42				
Tibial OST 3					6.10	1.91	19.48	<0.01				

involving kneeling or squatting [22]. Additional research has demonstrated a significant association between occupational activities such as sitting, standing, walking, climbing, and heavy lifting with moderate KOA, while kneeling and squatting are linked to severe KOA [23]. In ROAD study, Muraki revealed a significant association between kneeling, squatting, walking, and heavy lifting with minimum joint space width (mJSW). For osteophyte progression area (OPA), kneeling and squatting were significantly associated with larger osteophyte area, whereas other activities showed no such association [8]. However, in this study we didn't find the relation between occupational activities and joint space narrowing or osteophyte formation. The variations in our research findings may stem from differences in measurement methodologies. In their study, mJSN and OPA were estimated

using continuous values rather than categorical grades, but they did not correct the absolute value of the measurement in line with the height and weight. However, a meta-analysis suggested that early adulthood was a more crucial period for the development of OA while the recall of past activities may be biased or inaccurate [24]. Therefore, the relationship between occupational activities and JSN or osteophyte formation requires further investigation.

Pain is the most disabling symptom of osteoarthritis. Understanding the anatomical structures causing pain is critical, as future interventions need to be specifically targeted. This study found that only joint space narrowing was associated with knee pain, which was supported by previous literature. Nigoro reported that joint space narrowing had more profound effects on the medial side, while osteophytes significantly affected pain on the lateral side [25]. Furthermore, two meta-analyses concluded that there was no positive association between osteophytes and pain [26, 27]. Kornaat found that the association between osteophytes and knee pain would only prevail when an osteophytes were located in the patellofemoral compartment or when more than four osteophytes were present anywhere in the knee [26]. However, some articles reported an association between knee pain and osteophytes at the medial tibial plateau [28]. A major hallmark of OA is the loss of cartilage but the exact cause of knee pain among patients with OA remains intricate. As hyaline cartilage does not contain pain fibers, it cannot be the direct cause of pain in OA. Pain fibers are present in other structures in the knee, such as the joint capsule, periosteum, insertion sites of ligaments and muscles, the outer third of the menisci, and possibly the synovium. However, the role of these structures in pain remains uncertain. The relationship between knee pain and structural changes in OA remains future indepth studies.

The SF-12 Health Survey, with its Physical Component Summary (PCS) and Mental Component Summary (MCS) scores, is often used to assess the impact of knee osteoarthritis on a patient's quality of life. We only found that femoral osteophytes formation were correlated SF-12 physical component summary (PCS) scores. Osteophytes in knee osteoarthritis may affect the function of ligaments within the joint, leading to reduced joint mobility, increased pain, and stiffness, all of which negatively impact the physical function of patients. This deterioration in physical health is likely to be reflected by lower PCS scores on the SF-12 survey. Patients with more severe osteophyte formation may report greater difficulty with physical activities, more role limitations due to physical health, and increased bodily pain.

Radiographic changes, including both osteophytes and joint space narrowing, can affect the range of motion of the knee joint. Previous research has reported that the presence of osteophytes and the reduction in joint space width are associated with both active and passive flexion and extension ROM [29]. This finding underscores the necessity of removing osteophytes and performing osteotomy to create an appropriate joint space during knee arthroplasty. Additionally, in cases of primary knee osteoarthritis, the removal of marginal osteophyte proved capable of improving joint motion significantly [30].

Walking speed has been labelled a "functional vital sign" because this physical function measure has been associated with the prediction of falls, hospitalization, and mortality in elderly individuals. In KOA specifically, declining walking speed is associated with decreased knee confidence [31] and likelihood to undergo a knee replacement [32]. This study found that femoral osteophyte formation and severe joint space narrowing (Grade 3 only) were negatively correlated with gait speed. The worsening knee structure is leading to a protective gait strategy that decreases walking speed to minimize loading of the joint. Further, declining walking speed is consequently creating altered knee loading that leads to worsening knee structure [33–35]. Osteophyte formation and severe joint space narrowing are radiographic features correlated with articular cartilage degeneration within the tibiofemoral joint, which may influence knee physical function. Kijowski confirmed that osteophytes were the most sensitive radiographic finding for the detection of articular cartilage degeneration. Joint space narrowing and others were less sensitive radiographic features of osteoarthritis and rarely occurred without associated osteophyte formation [36]. This may account for the difference between osteophyte formation and joint space narrowing in their influences on walking speed. However, McDaniel demonstrated that radiographic JSN of the knee and ankle, rather than osteophytes, was associated with functional impairment [37]. Though a certain correlation between osteophytes and joint space narrowing might exist, this point was not considered in their analysis. Therefore, further research is needed to investigate the relationship between joint space narrowing, osteophyte formation, and gait speed. Additionally, the specific roles of tibial osteophytes and femoral osteophytes in affecting gait speed require further investigation.

This study found that severe tibial osteophytes may affect the performance of chair-stand test. However, joint space narrowing, femoral osteophytes, and mild tibial osteophytes appear to be unrelated to this test. Chair rising is a common movement in daily life, and the chair-stand test result is also considered to be associated with the risk of falling [38]. Little studies have reported the relationship between osteophytes and chair rising.

During dynamic flexion-extension movements, the femur primarily engages in rolling contact with the tibia, which increases the femoral cartilage contact area. In contrast, tibial cartilage experiences a reduced contact area, leading to higher localized loading [39, 40]. This may be a possible reason why tibial osteophytes, rather than femoral osteophytes, were associated with the chair-stand test. However, we do noted certain study suggested that the chair-stand test outcomes may not accurately reflect the knee joint loading. Rather, this test could potentially mirror lower limb muscle strength and the integrity of the neuromuscular system, rather than solely knee function [41].

Strength and limitation

Our study had strengths as well as limitations. First, to our knowledge, this was one of the first studies in China to separately examine the associations of joint space narrowing and osteophytes with physical function and quality of life. Our study employed a scientific and comprehensive sampling method, and involved a large sample size. Second, our study provided a basis for further understanding on the relationship between imaging changes and patients' symptoms and functions, which may potentially guide the treatment of diverse patient populations. Unlike previous literature, we included joint space narrowing and osteophyte formation as categorical variables in our study. The merit of this approach needs further investigated. However, categorical variables are more readily applicable in clinical practice compared to continuous variables. Surely, our study had certain limitations. Due to the limited sample size, this study included only patients with medial compartment knee osteoarthritis and examined the differences in risk factors for medial joint space narrowing and medial osteophytes, and their impact on function. The differences and effects associated with lateral joint space narrowing and osteophytes remain to be further investigated. However, from our clinical perspective, patients with isolated lateral compartment involvement are relatively rare. Secondly, patients with arthritis accompanied by mobility impairments caused by comorbid conditions were probably excluded from the study population, which may eventually lead to biased results. Additionally, all subjects came from a small town in the suburban area around Beijing, which might potentially reduce the representativeness of the sample.

Conclusion

Through the Shunyi Osteoarthritis Study, this cross-sectional study found that JSN and osteophyte were each independently associated with certain knee symptoms and function. JSN was associated with gait speed, knee pain, and ROM. Femoral osteophyte was correlated with gait speed, SF-12 physical component summary scores, and ROM. As for tibial osteophyte, its occurrence may affect ROM and the performance in the chair-stand test.

Abbreviations

KOA	Knee osteoarthritis
JSN	Joint space narrowing
BMI	Body mass index
ROM	Range of motion
VAS	Visual analogue scale
PCS	Physical component summary
MCS	Mental component summary
OR	Odds ratio
COEF	Coefficient
95%CI	95% confidence interval
mJSW	Minimum joint space width
OPA	Osteophyte progression area

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Author contributions

ZL and JL designed the study. LZ, JJ and CL assessed radiographs. LZ conducted the analyses, interpreted the findings, draw tables, and wrote the manuscript. ZL revised the manuscript. All authors have read and approved the manuscript.

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Data availability

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

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee of Peking University People's Hospital(2013-Z-24, 2018PHB166-01).

Consent for publication

Written informed consent was obtained from each participant prior to initiating any study procedures.

Competing interests

The authors declare no competing interests.

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