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Association between Dietary Habits and Knee Osteoarthritis in Japanese Older Adults: A Cross-Sectional Study

Kyoko Kondo[1], Satoko Ohfuji[1], Wakaba Fukushima[1], Shinji Takahashi[1], Hiromasa Miura[2], Shin-ichiro Takasugi[2], Yukihide Iwamoto[3] and Yoshio Hirota[1]

[1]*Faculty of Medicine, Department of Public Health, Osaka City University, Osaka, Japan*
[2]*Department of Rehabilitation Medicine, Kyushu University Hospital, Fukuoka, Japan*
[3]*Department of Orthopaedic Surgery, Graduate School of Medical Science, Kyushu University, Fukuoka, Japan*

Abstract

Background: To elucidate whether dietary habits affect knee osteoarthritis, we analyzed data from past regional screening programs for arthritis and osteoporosis.

Methods: Subjects comprised 493 Japanese individuals (120 men, 373 women; age range, 40-83 years) who participated in a regional screening program for arthritis and osteoporosis in a single town in southwestern Japan. Outcome measure was radiographically determined knee osteoarthritis, categorized according to the criteria of Kellgren and Lawrence as grade ≥ 2, 1 or 0. Associations between dietary habits and knee osteoarthritis were assessed by calculating odds ratios and 95% confidence intervals using a proportional odds model in logistic regression.

Results: Odds ratio for knee osteoarthritis was decreased with daily coffee consumption at 40 years of age (odds ratio=0.48, 95% confidence interval=0.28-0.83). Female sex (odds ratio=2.19, 95% confidence interval=1.15-4.15), age (3rd vs. 1st tertile: odds ratio=14.9, 95% confidence interval=8.07-27.5), weight at 40 years of age (3rd vs. 1st tertile: odds ratio=2.50, 95% confidence interval=1.41-4.43), previous knee injury (odds ratio=2.01, 95% confidence interval=1.24-3.24), and physical worker (odds ratio=2.09, 95% confidence interval=1.41-3.11) were significantly associated with knee osteoarthritis.

Conclusions: Daily coffee consumption at 40 years of age was inversely associated with severe radiographic knee osteoarthritis.

Keywords: Knee osteoarthritis; Epidemiology; Dietary habits; Coffee consumption

Introduction

Among elderly individuals, knee osteoarthritis (OA) is a common cause of pain and disability, which substantially limits the performance of various activities of daily living. Since the incidence of knee OA is expected to rise in accordance with the growth of the elderly population, the World Health Organization has suggested an urgent need for strategies to prevent OA [1].

Female sex [2-4], age [4-7], weight, body mass index (BMI) [3-5,7-15], history of knee injury [5,10,11, 13,16], occupational physical demands [8,11,13,16], and physical activity [3,9,16] are all risk factors for the development or progression of knee OA. Conversely, associations between knee OA and milk consumption [17,18] or antioxidant micronutrients [19,20] remain controversial, and little is known about the association between dietary habits and knee OA.

Dietary factors that play protective and anti-progressive roles in OA might prove useful for primary or secondary prevention. Therefore, we sought to elucidate whether dietary habits have an impact on knee OA, by analyzing data from past regional screening programs for arthritis and osteoporosis.

Material and Methods

Study design

This was a cross-sectional study.

Study subjects

Between 1994 and 1995, a regional screening program for OA and osteoporosis was conducted in a town within the Fukuoka Prefecture in south-western Japan. We advertised this study using a public relations magazine and sought to recruit participants. A total of 543 residents (133 men, 410 women) with a minimum age of 40 years provided informed consented and underwent the examination. Results are based on the analysis of 493 volunteers (120 men, 373 women) with available radiographs and completed self-administered questionnaires. The study protocol was approved by the Ethics Committee of the Osaka City University Faculty of Medicine.

Information collection

This program included the measurement of height, weight, weight-bearing anteroposterior knee radiographs during knee extension, and a self-administered questionnaire, which included questions assessing various health conditions, lifestyle, and diet.

Body mass index (BMI) was calculated as the weight (kg) divided by the square of height (m^2). Since data on the participants' heights at age 40 were unavailable, we used present height along with weight at 40 years in the calculation of BMI at age 40.

Radiographs of the tibiofemoral joint were classified by two expert rheumatologists following consultation with one another. The grade of radiographic knee OA was classified according to the criteria set forth

***Corresponding author:** Kyoko Kondo, Faculty of Medicine, Department of Public Health, Osaka City University, Japan, Tel: +81-6-6645-3756; Fax: +81-6-6645-3757; E-mail: kyou@med.osaka-cu.ac.jp

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by Kellgren and Lawrence [21] as: moderate or severe OA, grade ≥ 2; early OA, grade 1; or no OA, grade 0.

The self-administered questionnaire was designed to obtain information regarding a number of predictors. Since most cases of knee OA likely occur after the age of 40 years, weight and dietary habits (i.e., frequency of meat, fish, small fish with bones, egg, soy curd or *natto* (fermented soybeans), vegetables, fruit, cake, and coffee consumption) were determined at 40 years of age prior to the development of knee OA. A history of other conditions requiring medical treatment for ≥ 3 months, and history of knee injury requiring medical treatment for ≥ 2 weeks were recorded.

Lifestyle factors assessed included participants' predominant occupation, frequency of proper posture while sitting in Japanese-style on the floor (i.e., with knees bent and toes directly beneath the body), and participation in sports during school and recently were also assessed. To allow for comparisons with prior studies, we collected information regarding milk consumption at primary school, and/or junior high school, and in the present. Finally, participants' smoking status (i.e., "never", "past", or "current") and alcohol consumption (i.e., "never", "past" or "current") were ascertained.

Statistical analysis

Outcome measure was radiographically determined knee osteoarthritis, categorized according to the criteria of Kellgren and Lawrence as grade ≥ 2, 1 or 0.

Continuous explanatory variables were categorized into tertiles for comparison. Occupations were categorized according to the classifications of the Japan National Census and divided into types of physical workers (i.e., defined as "agricultural/fishery workers", "mining workers", or "factory/construction workers or laborers") and non-physical workers (all other occupations).

The Kruskal-Wallis rank test and the χ^2 test were used to compare characteristics according to outcome status, as appropriate.

Odds ratios (ORs) and 95% confidence intervals (95%CIs) were computed using the proportional odds model in logistic regression to express the relationship between various characteristics and knee OA [22]. We calculated p-values for score test for the proportional odds assumption, to confirm that the use of the proportional odds models was appropriate for the model. Trends for associations were assessed by assigning ordinal scores to the levels of independent variables.

Crude ORs of all variables, including dietary habits, were calculated initially. We then constructed a standard multivariate model, which included explanatory variables (excluding dietary habits) with significant crude ORs, as well as important pathophysiological variables, regardless of statistical significance. Since we wanted to examine whether excess weight is a predictor of knee OA rather than the reverse, we included weight at 40 years of age. In our previous study of female Japanese patients, weight at 40 years of age was the dominant predictor for severity of stair-climbing limitations [8]. Lastly, for dietary variables that showed crude ORs with p values of <0.1, we calculated ORs that were adjusted for age or variables in the standard multivariate model.

Values of $p<0.05$ were considered statistically significant. All analyses were performed using SAS version 9.1 software (SAS Institute, Cary, NC, USA).

Results

Of the 543 subjects (133 men, 410 women) who consented to participate in the study, 493 (120 men, 373 women) had completed radiographs and questionnaires for the analysis (perfect responders), while the remaining 50 (13 men, 37 women) were missing some data (imperfect responders). Selected characteristics between perfect and imperfect responders were compared to determine whether there was any potential bias. Imperfect responders showed a higher mean age than perfect responders (64.5 years vs. 60.4 years, respectively; p=0.016). Otherwise, perfect and imperfect responders were similar. For a given variable, missing data were seen in less than 3% of subjects.

Median age, height, and weight of all participants were 61.8 years, 154 cm, and 55 kg, respectively. Median age, height, and weight of male participants were 64.3 years, 162 cm, and 61 kg, respectively, whereas those of female participants were 60.8 years, 152 cm, and 54 kg, respectively. These values largely resembled the age-specific height and weight averages of Japanese adults according to the 1995 National Nutrition Survey [23].

Table 1 shows selected subject characteristics (excluding dietary habits) according to knee OA grade. Of all examined subjects, 65 (13%) displayed grade ≥ 2, 132 (27%) displayed grade 1, and 296 (60%) displayed grade 0 knee OA. Participants with a higher grade of knee OA were older, shorter, had a higher BMI at age 40 and at examination, and were more likely to have received treatment for knee injury, to be a physical worker, and to sit with good posture ($p<0.05$).

In univariate analysis, the following factors (excluding dietary habits) were significantly associated with knee OA: age (2nd, highest vs. lowest tertile: OR=4.16, 95%CI=2.41-7.16, OR=13.3, 95%CI=7.74-22.9); height (highest vs. lowest tertile: OR=0.61, 95%CI=0.40-0.93); BMI at 40 years of age (highest vs. lowest tertile: OR=1.95, 95%CI=1.26-3.01); BMI at examination (highest vs. lowest tertile: OR=1.98, 95%CI=1.28-3.05); history of treatment for knee injury (OR=2.73, 95%CI=1.75-4.26); occupation (OR=1.79, 95%CI=1.25-2.54); and greater frequency of sitting with good posture (OR=1.73, 95%CI=1.21-2.48). Although sex was not significantly associated with knee OA, the variable was included in the multivariate model, as prior findings documented a relationship between sex and knee OA [2-4]. A total of six variables were thus included in the first multivariate model (multivariate model 1 in Table 2): sex, age, BMI at 40 years of age, history of treatment for knee injury (≥2 weeks), occupation, and good posture while sitting. Since height showed a significant inverse association with knee OA ($p<0.05$) in univariate analysis, BMI at 40 years of age in multivariate model 1 was replaced with height and weight at 40 years of age (multivariate model 2 in Table 2). Before the proportional odds models were adapted to these models, we calculated the p-value for each score test for the proportional odds assumption (p=0.953, p=0.841). Use of both proportional odds models was determined to be appropriate.

In multivariate model 1, female sex was not significantly associated with knee OA. Increasing age was associated with a marked increase in OR for knee OA. A higher BMI at 40 years of age was also associated with a greater OR for knee OA (highest vs. lowest tertile: OR=1.76, 95%CI=1.10-2.84). Finally, subjects with a previous knee injury and those who were physical workers had a greater OR for knee OA.

In multivariate model 2, female sex was significantly associated with knee OA (OR=2.19, 95%CI=1.15-4.15). When comparing the highest versus the lowest tertile, older age (OR=14.9, 95 %CI=8.07-27.5) and higher weight at 40 years of age (OR=2.50, 95%CI=1.41-4.43) were both associated with knee OA. Similar to the observations

Variables[a]	n		Kellgren-Lawrence score			p
			Grade 2,3,4	Grade 1	Grade 0	
			(N=65)	(N=132)	(N=296)	
Sex, age, anthropometric factors, and medical history						
Sex						
male	120		15 (13%)	34 (28)	71 (59)	0.974[c]
female	373		50 (13%)	98 (26)	225 (60)	
Age (years)	493	range	50.2-83.7	43.1-83.2	40.1-81.0	<0.0001[b]
		median	67.8	65.3	57.3	
Height (cm)	493	range	141-174	136-174	137-183	0.031[b]
		median	153	153	154	
Weight at age 40 (kg)	493	range	39-90	35-75	36-95	0.506[b]
		median	54	53	53	
BMI at age 40 (kg/m^2)	493	range	17.8-35.4	16.0-29.8	15.8-30.3	0.002[b]
		median	22.9	22.1	21.8	
Weight (kg)	493	range	37-86	33-92	35-91	0.625[c]
		median	55	55	55	
BMI (kg/m^2)	493	range	18.3-38.7	15.9-34.9	13.8-32.2	0.043[c]
		median	23.9	23.2	22.9	
History of treatment for knee injury (≥2 weeks)						
none	408		45 (11%)	100 (25)	263 (64)	<0.0001 [c]
presence	85		20 (24%)	32 (38)	33 (39)	
Occupation and lifestyle						
Occupation						
Non-physical workers	276		27 (10%)	67 (24)	182 (66)	0.001[c]
Physical workers	217		38 (18%)	65 (30)	114 (53)	
Often good posture while sitting before age 40						
no	218		20 (9%)	52 (24)	146 (67)	0.003[c]
yes	275		45 (16%)	80 (29)	150 (55)	

a Variables are expressed as a percentage, b Kruskal-wallis test, c Chi-square test.

Table 1: Selected subject characteristics.

in model 1, a previous knee injury (OR=2.01, 95%CI=1.24-3.24) and physical worker (OR=2.09, 95%CI=1.41-3.11) were both associated with knee OA. Accordingly, we chose model 2 to represent our standard multivariate model.

We compared dietary habits according to knee OA grade. Participants with a lower grade of knee OA showed higher meat and coffee consumption, but lower consumption of small fish with bones at 40 years of age (Table 3). When we calculated crude ORs for dietary habits, meat and coffee consumption at 40 years of age, milk consumption at school (OR<1), recent milk consumption, and small fish with bones consumption at 40 years of age (1<OR) had p<0.1. When we calculated age-adjusted ORs, consumption of dietary factors, with the exception of daily coffee consumption at 40 years of age, was not related to knee OA (multivariate model 3 in Table 3). Finally, we included these dietary habits in our standard multivariate model and calculated the adjusted ORs (multivariate model 4 in Table 3). Daily coffee consumption at 40 years of age showed a significantly decreased OR for knee OA (OR=0.48, 95%CI=0.28-0.83), with a significant dose-response relationship (trend p=0.008). The consumption of other dietary factors was not related to knee OA.

Discussion

In the present study, the prevalence of knee OA (Kellgren and Lawrence grade ≥ 2) among men with a mean age of 62.9 years was approximately 12%. Further, 18.6% of men over the age of ≥ 65 years had knee OA. According to prior studies, the prevalence of knee OA among Chinese men in the 60- to 64-year-old age group was 10.0% [24], and among Japanese men over 64 years of age was 19.3% [25]. Those findings were thus in general agreement with the present results. Conversely, the prevalence of knee OA among women in the present study (mean age: 60 years) was 13%. Among women aged 60 years and above, the prevalence of knee OA was 22%. Another study from this time period (1998-1999) indicated a 35.8% prevalence of knee OA among Japanese women between 63 and 69 years of age [26]. Thus, by comparison, our results seem low. Since subjects in the present study were voluntary participants in a regional screening program for arthritis and osteoporosis, they may have represented a particularly health-conscious subset of the general population.

We found that daily coffee consumption at 40 years of age was inversely associated with severe radiographic knee OA. Many younger participants were daily coffee consumers at 40 years of age, and their age-adjusted OR was greater than their crude OR. Thus, when we calculated the adjusted OR in the same multivariate model among participants who were 50 years old or more (n=407), the adjusted OR decreased significantly (OR=0.54, 95%CI=0.30-0.98).

No previous studies appear to have reported on the association between coffee and OA. Our result may be associated with anti-oxidant or anti-inflammatory effects of coffee [27]. Some studies have reported on associations between antioxidant micronutrients and OA. One prior study indicated that a high intake of antioxidant micronutrients, particularly vitamin C, may reduce the risk of cartilage loss and disease progression among individuals with OA [19], and another indicated that oral intake of purple passion fruit peel extract reduced pain and stiffness and improved physical function in adult patients with knee OA, with the beneficial effects potentially attributable to the antioxidant and anti-inflammatory properties of the substance [28]. Wang et al.

	Univariate	Multivariate model 1[b]	Multivariate model 2[c]
	OR (95% CI)[a]	OR (95% CI)	OR (95% CI)
Sex, age, anthropometric factors, and medical history			
Sex			
female (vs. male)	0.98 (0.65-1.47)	1.49 (0.93-2.39)	2.19 (1.15-4.15)
Age			
40.0 - 56.7	1	1	1
56.8 - 65.1	4.16 (2.41-7.16)	3.54 (2.01-6.23)	3.75 (2.10-6.72)
65.2 - 83.7	13.3 (7.74-22.9)	12.4 (6.96-21.9)	14.9 (8.07-27.5)
p for trend	<0.0001	<0.0001	<0.0001
Height			
136 - 151	1		1
152 - 156	0.75 (0.49-1.15)		1.21 (0.71-2.05)
157 - 183	0.61 (0.40-0.93)		1.03 (0.53-2.00)
p for trend	0.020		0.864
Weight at 40 years of age			
35.0 - 49.0	1		1
50.0 - 55.0	1.13 (0.73-1.75)		1.27 (0.76-2.14)
56.0 - 95.0	1.45 (0.94-2.24)		2.50 (1.41-4.43)
p for trend	0.093		0.001
BMI at 40 years of age			
15.81 - 21.04	1	1	
21.05 - 23.18	1.55 (1.00-2.42)	1.27 (0.78-2.07)	
23.19 - 35.37	1.95 (1.26-3.01)	1.76 (1.10-2.84)	
p for trend	0.003	0.019	
Weight			
33.0 - 51.0	1		
52.0 - 58.0	1.30 (0.84-2.02)		
59.0 - 96.0	1.46 (0.94-2.27)		
p for trend	0.095		
BMI			
13.84 - 21.874	1		
21.875 - 24.44	1.30 (0.83-2.02)		
24.45 - 38.79	1.98 (1.28-3.05)		
p for trend	0.002		
History of treatment for knee injury (≥2 weeks)			
yes (vs. no)	2.73 (1.75-4.26)	2.07 (1.29-3.33)	2.01 (1.24-3.24)
Occupation and lifestyle			
Occupation			
physical worker (vs. non-physical worker)	1.79 (1.25-2.54)	1.93 (1.31-2.85)	2.09 (1.41-3.11)
Often good posture while sitting before age 40			
yes (vs. no)	1.73 (1.21-2.48)	1.19 (0.78-1.81)	1.23 (0.80-1.87)

[a] OR = odds ratio, 95% CI = 95% confidence interval

[b] Multivariate model included sex, age, BMI at 40 years of age, history of treatment for knee injury, occupation, and often good posture while sitting before age 40. Analysis based on a sample size of 493.

[c] Multivariate model included sex, age, height, weight at 40 years of age, history of treatment for knee injury, occupation, and often good posture while sitting before age 40. Analysis based on a sample size of 493.

Table 2: Association between selected characteristics and knee OA among Japanese.

suggested a beneficial effect of fruit consumption and vitamin C intake in healthy middle aged subjects as they are associated with a reduction in bone size and the number of bone marrow lesions, both of which are important in the pathogenesis of knee OA [20].

On the other hand, supplementary vitamin E does not affect the loss of cartilage volume in knee OA, according to a double-blind randomized placebo-controlled study [29]. Likewise, vitamin D supplementation did not reduce knee pain or cartilage volume loss in patients with symptomatic knee OA in a randomized controlled trial [30]. A prospective examination is needed to clarify the association between coffee consumption and knee OA.

In the present study, crude ORs of meat consumption at 40 years of age and milk consumption at school decreased, and many younger participants were daily meat consumers at 40 years of age and daily milk consumers at school. Moreover, milk was generally not supplied during the time when our subjects aged 56 years old or older were in school. Age-adjusted ORs of these dietary habits increased, and were not significant. The decreased crude ORs may thus have been confounded by age. Conversely, daily consumption of small fish with bones at 40 years of age and recent daily milk consumption increased the crude ORs. Many older participants were daily consumers of small fish with bones at 40 years of age and recent daily milk consumers. Since the p-values of these dietary habits increased after adjusting for

Variables	n	Kellgren-Lawrence score			Univariate	Multivariate model 3[b]	Multivariate model 4[c]
		Grade 2, 3, 4	Grade 1	Grade 0			
		(N=65)	(N=132)	(N=296)	OR (95 CI)[a]	OR (95% CI)	OR(95%CI)
Dieary habits							
Meat consumption at 40 years of age							
none	59	12 (20%)	19 (32)	28 (47)	1	1	1
a few times a week	351	51 (15%)	94 (27)	206 (59)	0.64 (0.38-1.08)	0.75 (0.43-1.30)	0.84 (0.48-1.46)
every day	82	2 (2%)	19 (23)	61 (74)	0.29 (0.15-0.58)	0.57 (0.27-1.21)	0.70 (0.32-1.52)
p for trend					0.0004	0.139	0.361
Small fish with bones consumption at 40 years of age							
none	102	12 (12%)	25 (25)	65 (64)	1	1	1
a few times a week	289	41 (14%)	69 (24)	179 (62)	1.11 (0.70-1.75)	1.10 (0.67-1.80)	1.08 (0.65-1.80)
every day	93	11 (12%)	37 (40)	45 (48)	1.64 (0.94-2.84)	1.23 (0.68-2.21)	1.18 (0.64-2.16)
p for trend					0.079	0.499	0.592
Coffee consumption at 40 years of age							
none	256	49 (19%)	85 (33)	122 (48)	1	1	1
a few times a week	103	11 (11%)	24 (23)	68 (66)	0.47 (0.30-0.75)	0.73 (0.45-1.20)	0.75 (0.45-1.25)
every day	134	5 (4%)	23 (17)	106 (79)	0.23 (0.15-0.38)	0.44 (0.26-0.75)	0.48 (0.28-0.83)
p for trend					<0.0001	0.002	0.008
Milk consumption at school							
none	372	53 (14%)	106 (28)	213 (57)	1	1	1
a few times a week	45	5 (11%)	9 (20)	31 (69)	0.62 (0.33-1.19)	0.77 (0.38-1.57)	0.86 (0.42-1.79)
every day	74	7 (9%)	17 (23)	50 (68)	0.64 (0.38-1.08)	1.10 (0.61-1.97)	1.13 (0.61-2.08)
p for trend					0.052	0.931	0.804
Recent milk consumption							
none	81	8 (10%)	16 (20)	57 (70)	1	1	1
a few times a week	106	14 (13%)	25 (24)	67 (63)	1.39 (0.76-2.56)	1.70 (0.88-3.28)	1.82 (0.92-3.60)
every day	306	43 (14%)	91 (30)	172 (56)	1.79 (1.07-3.01)	1.37 (0.78-2.41)	1.38 (0.76-2.49)
p for trend					0.021	0.509	0.586

[a] OR = odds ratio, 95% CI = 95% confidence interval
[b] Adjusted by age.
[c] Adjusted by sex, age, height, weight at 40 years of age, history of treatment for knee injury, occupation, and often good posture while sitting before age 40.

Table 3: Association between dietary habits and knee OA among Japanese.

age, the increased crude ORs were confounded by age. Two studies indicated that daily consumption of milk [17] or a nutritional beverage containing milk-based micronutrients [18] may have beneficial effects on symptomatic knee OA in the elderly.

Other factors associated with knee OA were female sex, older age, excess weight at 40 years of age, a previous knee injury, and physical work. Many previous epidemiologic studies have reported strong associations between female sex or older age and knee OA [2-4].

A number of reports from the Framingham Study [3,9,12] have identified relationships between weight status and OA risk. We analyzed 5 anthropometric factors, i.e., height (present), weight (present, age 40), and BMI (present, age 40). Greater height was significantly and inversely associated with radiographic knee OA in univariate analysis. Knee pain was associated with shorter height in male Japanese patients with knee OA [6]. In the present study, however, height was not associated with knee OA in multivariate analysis. Weight (present, age 40) was significantly and positively associated with knee OA after adjustment for other factors. The model hat included BMI as an anthropometric factor was unclear in terms of whether high weight and shorter height are positively associated with knee OA. When examining risk factors for knee OA, it is important to investigate associations with BMI, which is an indicator of obesity. Furthermore, weight and height should be considered as explanatory variables in multivariate models, as well as BMI.

Joint injury is a well-known risk factor for knee OA [5,16]. Indeed, knee injury or previous knee pain and/or swelling have been shown to have positive associations with knee OA among Japanese females [8,11]. In Japan, a case-control study reported that sedentary work during initial employment and total numbers of years working were associated with knee OA after controlling for other potential risk factors [11]. Finally, knee OA patients who were classified as physical workers tended to show severe limitations during stair climbing [8]. Good posture while sitting before age 40 was not associated with knee OA after adjustment for other factors. In our previous study, male knee OA patients who often sit with good posture showed more severe knee OA pain when climbing and/or descending stairs than individuals who sometimes or do not sit with good posture [6]. This different result might be due to symptomatic outcomes.

The present study has some limitations. Since a cross-sectional design was used as an epidemiological method to establish a hypothesis for disease prevention, a sample size of 493 subjects may have been insufficient. In order to obtain valid results, we calculated ORs for dietary habits adjusted by 5 factors (sex, age, weight at 40 years of age, history of treatment for knee injury, and occupation) that showed $p<0.05$ in the standard multivariate model. Daily coffee consumption at 40 years of age showed a significantly decreased OR for knee OA (OR=0.49, 95%CI=0.28-0.84), with a significant dose-response relationship (trend p=0.009). The dietary factors in this model showed ORs with the same direction and similar pattern as in the multivariate model 4 (data not shown).

In addition, we did not assess the intra- and inter-observer reliability of radiographic diagnosis. Finally, recall bias of self-reported information represents another potential limitation; we were unable to assess the reliability of the recalled body weights, lifestyle, or food consumption at 40 years old. One study found that, in participants who were 50 years old, a correlation existed between recalled and measured weights at 18 and 40 years of age (r=0.87 and 0.95, respectively) [31]. Hence, in our study, body weights at 40 years of age may be considered reliable.

In summary, we analyzed data from past regional screening programs for arthritis and osteoporosis to elucidate whether dietary habits have an impact on knee OA. Daily coffee consumption at 40 years old was inversely associated with severe knee OA as assessed radiographically. A prospective study should be conducted to further clarify the association between knee OA and coffee.

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