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Few studies have estimated the association between shift work and the risk of knee osteoarthritis (KOA). This retrospective cohort study showed that shift work was independently associated with the elevated risk of KOA. The longer the duration of shift work employment, the greater the risk, but the risk gradually decreased after leaving shift work.

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Key terms: China; Chinese worker; circadian rhythm; cohort study; knee osteoarthritis; metabolic disorder; occupational health; retrospective cohort study; shift rotation; shift work; shift worker; worker

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Shift work and the risk of knee osteoarthritis among Chinese workers: a retrospective cohort study

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Objectives Shift work is associated with metabolic disorders as it disturbs circadian rhythms. However, the potential association of shift work with knee osteoarthritis (KOA), a metabolic-related disease, has not been confirmed. The objective of this study was to quantify the association of shift work with the risk of KOA.

Methods This retrospective cohort study comprising 13 741 retired workers from the Dongfeng Motor Corporation. KOA was defined by knee pain and clinical X-ray radiographs. Occupational history, including job description and shift work, was collected from face-to-face interviews using questionnaires. Cox proportional hazards regression models were used to estimate exposure–response relationships.

Results During the 590 085 person-years of follow-up, a total of 847 cases of KOA (incidence of KOA was 143.5 per 100 000 person-years) were identified. After adjusting for potential confounders, shift work was independently associated with an elevated risk of KOA [hazard ratio (HR) 1.19, 95% confidence interval 1.03–1.36]. Compared with daytime workers, the risk of KOA increased with prolonged periods of shift work; the HR of KOA for participants with 1–9 years, 10–19 years, and ≥20 years shift work were 1.03 (95% CI 0.84–1.26), 1.19 (95% CI 0.98–1.46), and 1.42 (95% CI 1.15–1.76), respectively. The HR for KOA associated with shift work gradually decreased as the period after finishing shift work increased.

Conclusion Our results indicated that shift work could be an independent risk factor for KOA.

Key terms China; circadian rhythm; metabolic disorder; occupational health; shift rotation; shift worker.

Shift work – including night shifts, rotating shifts, and irregular schedules – is becoming increasingly common worldwide due to the rapid progress of industrialization and service demands. As much as 20% of the total active population participate in shift work schedules in industrialized countries worldwide (1). This employment practice typically divides a day into shifts, setting periods of time during which different groups of workers take up their posts to make use of or provide services throughout all 24 hours of each day.

Normally the body has fixed circadian rhythms, also known as the circadian clock, which presents in stable sleeping and feeding patterns. In shift work, the time of work activities, sleeping, and even diet for workers need to be constantly changed. Studies have reported that shift work, particularly night shifts, can disrupt the circadian clock (2, 3). The circadian clock must be reset on a routine basis to ensure synchrony between the organism and the environment, as well as to maintain internal homeostasis including metabolism, inflammation, and hormone production (4). When the circadian clock is disturbed by shift work, an imbalance in internal homeostasis will occur. Previous studies have suggested that shift work increases the risk of chronic metabolic-related diseases (5–7). Furthermore, Berenbaum reported that the circadian clock regulated the homeostasis and function of musculoskeletal tissues including muscles, tendons, ligaments, bone, cartilage, subchondral bone, and synovial. Thus, disturbance of homeostasis of musculoskeletal tissues could occur due to disruption of the circadian clock (8).

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Knee osteoarthritis (KOA) – manifested as degenerative arthritis – is a disease of the entire joint, involving cartilage, synovial tissue, tendons, ligaments, and subchondral bone (9). Common and disturbing symptoms of KOA include pain or aching stiffness in or around the knee, localized swelling around the knee, and/or limited motion of the knee. KOA most commonly affects people aged ≥45 years. In 2016, it was reported that 301.57 million people worldwide were affected by osteoarthritis, and 14.70 million new cases were recorded (10). Moreover, KOA is currently the leading cause of lower-limb disability in adults and results in a huge medical burden worldwide. Results of the 2016 Global Burden of Disease Study showed that osteoarthritis caused 16.28 million disability-adjusted life-years in 195 countries (11). Therefore, potential risk factors for KOA have received widespread attention.

Published reports have suggested that KOA is influenced by obesity, aging, and overloaded external force on knee joints such as heavy loads or repeated bending from occupational activities or sports (12–14). Recently, evidence is emerging that systemic metabolism plays a key role in the onset and progression of KOA (15). Several studies have demonstrated that metabolic disorders are important risk factors of KOA (16–18). Our previous research also showed that hyperlipidemia was positively independently associated with an elevated risk of KOA in a cohort study (19). However, whether metabolic disorders caused by the disturbance of the circadian clock following shift work is related to KOA remains to be established. Few studies have focused on the association of shift work with the risk of KOA.

In order to fill the gap in knowledge, we conducted the present retrospective cohort study among 13 741 retired workers from the Dongfeng Motor Corporation (20). The objective of this study was to quantify the association of shift work with the risk of KOA and to evaluate the persistent association of shift work with the risk of KOA after leaving shift work.

Methods

Study population

A group of 14 438 retired workers from Dongfeng Motor Corporation, ie, all of the participants that undertook a physical examination at the Dongfeng Central Hospital, were recruited in this study. In 2013, trained professionals interviewed all participants face-to-face and collected information on demographics, knee pain, medical history (osteoarthritis, rheumatoid arthritis, and accidental injury), occupational history (job titles, calendar years of each job for each individual's full duration of employment, job content, and shift work experience), and lifestyle (smoking, alcohol drinking, and physical exercise). After the interview, all participants underwent examination of the knee joint including tenderness, range of motion, extension test, and McMurray's test (21). A total of 13 741 participants were included after excluding individuals with incomplete information on occupational history or knee health status, knee surgery caused by accidental injury that was associated with secondary KOA, history of rheumatoid arthritis, diagnosis of KOA prior to the start of employment, diagnosis of KOA prior to the start of shift work.

This study was approved by the Medical Ethics Committee of Dongfeng General Hospital, Dongfeng Motor Corporation, and the School of Public Health, Tongji Medical College, Huazhong University of Science and Technology. All participants signed written informed consent.

Follow-up

The first year of employment for each participant was retrospectively assigned as the beginning of the follow-up period. The end of the follow-up period was defined as the year of physician-diagnosed KOA or 2013, whichever came first.

Assessment of KOA

Self-reported knee pain was defined when one or both knee(s) met at least one of the following conditions: (i) pain or aching stiffness in or around the knee on most days for ≥1 month during the preceding 12 months; (ii) persistent pain or aching stiffness in or around the knee within the past week.

Information regarding the clinical diagnosis of KOA and the year of diagnosis was collected from the questionnaires and confirmed by insurance records and treatment information. Clinical KOA cases were only defined if the participant had knee pain (as defined above) and the bilateral weight-bearing anteroposterior X-ray radiographs showed a Kellgren & Lawrence grade ≥2 in at least one knee (22).

Assessment of shift work

Shift work was identified as working with a schedule involving unusual working hours as opposed to the normal daytime work schedule, ie, 08:00–17:00 hours for ≥1 year. There were two common kinds of shift work for the participants in this study: two-shifts including day work (08:00–17:30) and night work (17:30–02:30) shifts on a weekly rotation; three-shifts during which three crews of workers succeeded each other at 08:00, 16:00, and 00:00 hours. The workers in any kind of shift work took turns to work in the early morning and at night. Shift work duration was calculated by the starting year of shift work to the earliest year out of the following: the end of shift work, the first year of clinical KOA diagnosis, or 2013, and was categorized into 1–9, 10–19, and ≥20 years.

Years after leaving shift work was the duration from the year leaving shift work to the end of the follow-up period. The duration of leaving shift work was divided into tertiles based on the duration of shift work.

Assessment of covariates

Body weight and height was measured to the nearest 0.1 kg and 0.1 cm, with participants wearing light indoor clothing and no shoes. Body mass index (BMI) was calculated from weight in kilograms divided by body height in squared meters.

Information regarding smoking status (current/former/never), drinking status (current/former/never), and physical exercise was collected from the questionnaires. Participants who had been smoking as much as one cigarette per day for ≥6 months were considered current smokers, and those who had been drinking alcohol as often as once per week for ≥6 months were considered current drinkers. Physical exercise was defined as regular exercise of ≥20 minutes per day over the past 6 months (20).

Based on the job held for the longest duration, the work posture was grouped into sitting, standing, squatting or kneeling, or bending if such posture was maintained for more than half of one work shift (ie, ≥4 hours for most cases) according to the job content description. The occupational chemicals (eg, industrial dust) level for each job title in the workplace came from the company occupational hazard monitoring records, and was categorized into "yes" when the concentrations of chemicals were higher than the national occupational chemicals exposure limit. Early retirement was defined as retiring before the statutory age of retirement (55 years for male workers and 50 years for females).

Statistical analyses

Basic characteristics of participants were presented as means and standard deviation (SD) for normally distributed continuous variables and as numbers and percentages for categorical variables. Continuous variables were compared using ANOVA analysis across shift work duration, whereas categorical variables were compared using Chi-square test.

Cox proportional hazards regressions were used to evaluate the association of shift work with KOA, and hazard ratios (HR) and 95% confidence intervals (CI) were calculated. We used age as the time variable to define the risk sets for incidence, and we used cases of KOA as the outcome variable in regression analyses. The basic model 1 only included shift work. Model 2 also included gender and BMI (continuous) as they were reported to be significantly associated with the risk of KOA (23). Model 3 also included lifestyle variables (smoking, drinking, and physical exercise). Model 4 was further adjusted for working years. Model 5 was further adjusted for work posture and occupational chemicals, for the reason that shift work experience may vary according to different jobs. Models were conducted with daytime workers as the reference group.

Multivariable stepwise Cox proportional hazards regressions that started with relevant factors (including gender, BMI, smoking, drinking, physical exercise, working years, work postures, occupational chemicals, and shift work) and ended with variables that were statistically significantly associated with a P-value <0.05 in a stepwise selection procedure, were used to explore the independent association between shift work and risk of KOA.

To investigate the combined effects of shift work and other factors on KOA, we estimated HR by crossed dichotomized shift work (shift worker = A+; daytime worker = A−) and each of the other factors (eg, obesity = B+; normal or low body weight = B−). The relative excess risk due to interaction (RERI) (calculated as $HR_{A+B+} - HR_{A+B-} - HR_{A-B+} + 1$) was used to evaluate additive interaction (24). Multiplicative interaction was examined by adding an interaction term of shift work (A+/A−) and each of the other factors (B+/B−) to the Cox proportional hazards regressions model.

To evaluate the persistent role of shift work in the risk of KOA, the HR of KOA associated with shift work was calculated, respectively, at different levels of duration of leaving shift work. Linear trend tests were conducted by including the median value for each level of duration of leaving shift work as a continuous variable in the models.

Statistical tests were two-sided with a significance set at P<0.05. All statistical analyses were performed using SAS 9.4 software (SAS Institute, Cary, NC, USA).

Results

The basic characteristics of the participants in 2013 are shown in table 1. A total of 13 741 participants (females 7453, 54.2%) were included in the analysis and the mean age was 64.4 (SD 8.6) years old. A total of 5390 (39.2%) workers had engaged in shift work, including 1877 (13.7%) workers who had undergone shift work for 1–9 years, 1859 (13.5%) for 10–19 years, and 1654 (12.0%) for ≥20 years. Participants with a longer duration of shift work were more likely to be males, current smokers, older, have worked in awkward postures, and been exposed to occupational chemicals.

Table 1. Basic characteristics of study population according to shift work. [BMI=body mass index; KOA=knee osteoarthritis; NA=not applicable; SD=standard deviation]. Continuous variables were compared using ANOVA analysis across shift work duration, whereas categorical variables were compared using Chi-square test.

Variables	Total		Duration of shift work								P-value
			Never		1–9 years		10–19 years		≥20 years		
	N (%)	Mean (SD)	N (%)	Mean (SD)	N (%)	Mean (SD)	N (%)	Mean (SD)	N (%)	Mean (SD)	
Female gender	7453 (54.2)		4512 (54.0)		1208 (64.4)		1068 (57.4)		665 (40.2)		<0.001
Age (years)		64.4 (8.6)		65.4 (8.2)		62.9 (8.6)		63.5 (8.1)		64.7 (7.5)	<0.001
BMI (kg/m^2)		24.2 (3.3)		24.2 (3.3)		24.2 (3.3)		24.2 (3.4)		24.2 (3.3)	0.836
Smokers											<0.001
Non	9690 (70.7)		5966 (71.6)		1407 (75.0)		1292 (69.7)		1025 (62.0)		
Current	2155 (15.8)		1259 (15.1)		270 (14.4)		291 (15.7)		335 (20.3)		
Former	1868 (13.6)		1105 (13.3)		198 (10.6)		271 (14.6)		294 (17.8)		
Drinkers											<0.001
Non	9354 (68.3)		5784 (69.5)		1328 (70.9)		1244 (67.1)		998 (60.4)		
Current	3473 (25.3)		2035 (24.4)		439 (23.4)		479 (25.8)		520 (31.5)		
Former	50 (6.4)		507 (6.1)		105 (5.6)		130 (7.0)		134 (8.1)		
Physical exercise	12379 (90.1)		7504 (89.9)		1695 (90.3)		1666 (89.6)		1514 (91.5)		0.180
Work postures											<0.001
Sitting	4781 (34.9)		3473 (41.8)		551 (29.5)		406 (21.9)		351 (21.3)		
Standing	6011 (43.9)		3218 (38.7)		917 (49.0)		983 (53.0)		893 (54.1)		
Bending	1868 (13.6)		1016 (12.2)		254 (13.6)		335 (18.1)		263 (15.9)		
Squatting or kneeling	1022 (7.5)		600 (7.2)		148 (7.9)		130 (7.0)		144 (8.7)		
Occupational chemicals	1728 (12.6)		883 (10.6)		244 (13.0)		298 (16.0)		303 (18.3)		<0.001
Shift work											
Daytime workers	8351 (60.8)		8351 (100.0)		NA		NA		NA		<0.001
Two shifts	4079 (29.7)		NA		1489 (79.3)		1383 (74.4)		1207 (73.0)		
Three shifts	1311 (9.5)		NA		388 (20.7)		476 (25.6)		447 (27.0)		
Early retirement years		1.7 (3.5)		1.6 (3.5)		2.2 (4.0)		2.0 (3.5)		1.4 (2.8)	<0.001
KOA	874 (6.4)		531 (6.4)		114 (6.1)		120 (6.5)		109 (6.6)		0.933

During the 590 085 person-years of follow-up, we identified 847 cases of KOA. The incidence of KOA in this cohort was 143.5 per 100 000 person-years. After adjusting for gender and BMI, the HR of KOA among shift workers was 1.15 (95% CI 1.01–1.32) when compared with daytime workers. Controlling for lifestyles and occupational characteristics did not change this association. Different shift types showed similar associations with the risk of KOA; the fully adjusted HR for two shifts and three shifts were 1.19 (95% CI 1.02–1.38) and 1.19 (95% CI 0.94–1.50), respectively. Both continuous and categorical analyses suggested positive exposure–response relationship between prolonged periods of shift work and the risk of KOA. Compared with daytime workers, the HR of KOA among participants with 1–9, 10–19, and ≥20 years of shift work were 1.03 (95% CI 0.84–1.26), 1.19 (95% CI 0.98–1.46), and 1.42 (95% CI 1.15–1.76), respectively, after adjusting for gender, BMI, lifestyles, and occupational characteristics. In the fully adjusted model, each 5-year increase in the duration of shift work was associated with a 5% increase in the risk of KOA (table 2).

In the stepwise multivariate Cox proportional hazards regression analyses, the following associations remained stable: between shift work and KOA (HR 1.16, 95% CI 1.01–1.33), between categorical shift work duration and KOA (HR 1.02, 1.16, 1.36 for 1–9, 10–19, and ≥20 years of shift work), and between continuous shift work duration and KOA (HR 1.04, 95% CI 1.01–1.08) (table 3).

The results of the combined effects of shift work with other factors (gender, obesity, physical exercise, smoking, drinking, work posture, occupational chemicals, and early retirement) in relation to the risk of KOA are shown in table 4. Compared with participants without shift work and lower BMI, the HR for KOA among those with shift work and lower BMI, without shift work and higher BMI, and with shift work and higher BMI were 1.17 (95% CI 0.43–3.23), 2.18 (95% CI 1.16–4.07), and 2.60 (95% CI 1.38–4.88), respectively. Women with shift work showed the highest risk of KOA (HR 2.62, 95% CI 2.08–3.30) compared with men with daytime work. However, neither the multiplicative interaction terms nor the RERI were statistically significant, suggesting that the hypothesis of multiplicative interaction or additive interaction between shift work and other risk factors cannot be rejected.

We then estimated the persistent role of shift work in the risk of KOA after leaving shift work. As shown in figure 1, among participants with ≥20 years of shift work, the HR of KOA associated with shift work showed a decreasing trend as the duration of leaving shift work

Table 2. Hazard ratios (HR) and 95% confidence intervals (CI) for knee osteoarthritis (KOA) by shift work. [NA=not applicable].

Variables	KOA	Model 1 [a]		Model 2 [b]		Model 3 [c]		Model 4 [d]		Model 5 [e]	
	N (%)	HR	95% CI	HR	95% CI	HR	95% CI	HR	95% CI	HR	95% CI
Shift work											
No	531 (6.4)	1	reference	1	reference	1	reference	1	reference	1	reference
Yes	343 (6.4)	1.14	0.99–1.31	1.15	1.01–1.32	1.14	1.00–1.31	1.16	1.01–1.33	1.19	1.03–1.36
Shift work duration (categorical)											
Daytime workers (years)	531 (6.4)	1	reference	1	reference	1	reference	1	reference	1	reference
1-9	114 (6.1)	1.13	0.92–1.38	1.03	0.84–1.27	1.03	0.84–1.27	1.02	0.83–1.25	1.03	0.84–1.26
10-19	120 (6.5)	1.17	0.96–1.43	1.16	0.95–1.41	1.15	0.95–1.41	1.16	0.95–1.41	1.19	0.98–1.46
≥20	109 (6.6)	1.13	0.92–1.38	1.29	1.05–1.58	1.28	1.04–1.57	1.36	1.10–1.68	1.42	1.15–1.76
Shift work duration (per 5-year increase)	NA	1.02	0.99–1.05	1.04	1.01–1.07	1.04	1.01–1.07	1.04	1.01–1.08	1.05	1.02–1.09
Shift work types											
Daytime workers	531 (6.4)	1	reference	1	reference	1	reference	1	reference	1	reference
Two shifts	259 (6.4)	1.14	0.99–1.33	1.15	0.99–1.34	1.15	0.99–1.33	1.16	1.01–1.35	1.19	1.02–1.38
Three shifts	84 (6.4)	1.14	0.91–1.44	1.14	0.91–1.44	1.14	0.90–1.44	1.16	0.92–1.46	1.19	0.94–1.50

[a] Crude HR.
[b] Adjusted for gender, and body mass index (BMI) (continuous).
[c] Model 2 + smoking, drinking, and physical exercise.
[d] Model 3 + working years.
[e] Model 4 + work posture, and occupational chemicals.

Table 3. Hazard ratios (HR) and 95% confidence intervals (CI) for knee osteoarthritis (KOA) from multivariate stepwise cox proportional hazards regression model. [BMI=body mass index; NA=not applicable].

Variables	KOA	Model 1 [a]		Model 2 [b]		Model 3 [c]	
	N (%)	HR	95% CI	HR	95% CI	HR	95% CI
Shift work							
No	531 (6.4)	1	reference				
Yes	343 (6.4)	1.16	1.01–1.33				
Shift work duration (categorical)							
Daytime workers (years)	531 (6.4)			1	reference		
1–9	114 (6.1)			1.02	0.83–1.25		
10–19	120 (6.5)			1.16	0.95–1.41		
≥20	109 (6.6)			1.36	1.10–1.68		
Shift work duration (per 5-years increase)	NA					1.04	1.01–1.08
Gender							
Male	264 (4.2)	1	reference	1	reference	1	reference
Female	610 (8.2)	2.67	2.18–3.27	2.67	2.18–3.27	2.67	2.18–3.28
BMI (kg/m^2)	NA	1.07	1.06–1.09	1.07	1.05–1.09	1.07	1.05–1.09
Drinkers							
Non	638 (6.8)	1	reference	1	reference	1	reference
Current	186 (5.4)	1.44	1.20–1.72	1.43	1.19–1.72	1.43	1.20–1.72
Former	50 (5.7)	1.41	1.04–1.92	1.40	1.03–1.91	1.40	1.03–1.91

[a] Initially included gender, BMI (continuous), smoking, drinking, physical exercise, working years, work postures, occupational chemicals, and shift work.
[b] Initially included gender, BMI (continuous), smoking, drinking, physical exercise, working years, work postures, occupational chemicals, and duration of shift work (categorical).
[c] Initially included gender, BMI (continuous), smoking, drinking, physical exercise, working years, work postures, occupational chemicals, and duration of shift work (continuous).

increased, with a P-value for trend of 0.009; however, the HR decreased without statistical significance among those with 1–9 or 10–19 years of shift work (P-values for trend 0.162 and 0.312, respectively).

In order to prove the credibility of our results, we examined the association of gender, BMI, lifestyle, awkward work postures, and working years with KOA. As shown in supplementary table S1 (www.sjweh.fi/show_abstract.php?abstract_id=3861), female gender (HR 2.87, 95% CI 2.48–3.32), obesity (HR 1.09, 95% CI 1.06–1.11), standing (HR 1.20, 95% CI 1.03–1.39) or bending work posture (HR 1.19, 95% CI 0.96–1.47), and early retirement (HR 1.61, and 4.07 for 1–4 and ≥5 years of early retirement, respectively) were risk factors of KOA.

Discussion

In the present study, we identified a positive association between shift work and the risk of KOA among 13 741 retired workers. There was an exposure–response relationship between prolonged shift work duration and the elevated risk of KOA. However, the association of shift work with KOA gradually decreased as the duration of

Table 4. Combined effect of shift work and other potential factors on the risk of knee osteoarthritis (KOA). [BMI=body mass index; CI=confidence interval; HR=hazard ratio; RERI=relative excess risk due to interaction].

	Daytime workers			Shift workers			Test for multiplicative interaction		Test for additive interaction	
	KOA N (%)	HR	95% CI	KOA N (%)	HR	95% CI	HR	95% CI	RERI	95% CI
Gender [a]										
Male	158 (4.1)	1	reference	106 (4.3)	1.20	0.94–1.54				
Female	373 (8.3)	2.25	1.81–2.81	237 (8.1)	2.62	2.08–3.30	0.97	0.72–2.81	0.21	-0.01–0.43
BMI (kg/m^2) [a]										
<24	10 (3.8)	1	reference	6 (3.5)	1.17	0.43–3.23				
≥24	521 (6.4)	2.18	1.16–4.07	337 (6.5)	2.60	1.38–4.88	1.02	0.37–2.82	0.25	-0.85–1.35
Physical exercise [a]										
No	58 (6.9)	1	reference	34 (6.6)	1.16	0.76–1.78				
Yes	473 (6.3)	1.06	0.80–1.39	309 (6.3)	1.26	0.95–1.68	1.03	0.66–1.62	0.05	-0.44–0.54
Smoking [b]										
No	435 (7.3)	1	reference	269 (7.2)	1.17	1.01–1.36				
Yes	96 (4.1)	0.93	0.72–1.20	74 (4.5)	1.14	0.87–1.51	1.06	0.75–1.48	0.05	-0.34–0.23
Drinking [b]										
No	397 (6.9)	1	reference	241 (6.8)	1.14	0.97–1.34				
Yes	134 (5.3)	1.38	1.11–1.70	102 (5.6)	1.76	1.39–2.22	1.13	0.83–1.53	0.10	-0.24–0.45
Work posture [a]										
Sitting	305 (6.2)	1	reference	270 (6.6)	1.30	1.11–1.54				
Others	226 (6.5)	1.29	1.08–1.55	73 (5.6)	1.24	0.95–1.61	0.76	0.56–1.03	0.27	-0.01–0.55
Occupational chemicals [a]										
No	482 (6.4)	1	reference	283 (6.2)	1.15	0.99–1.33				
Yes	49 (5.6)	0.81	0.60–1.09	60 (7.1)	1.28	0.97–1.68	1.44	0.96–2.16	0.32	-0.10–0.74
Early retirement [a]										
No	308 (5.4)	1	reference	171 (5.2)	1.13	0.94–1.37				
Yes	223 (8.3)	2.15	1.80–2.58	172 (8.2)	2.46	2.02–3.00	1.01	0.77–1.32	0.17	-0.33–0.68

[a] Models were adjusted for working years.
[b] Models were adjusted for working years and gender.

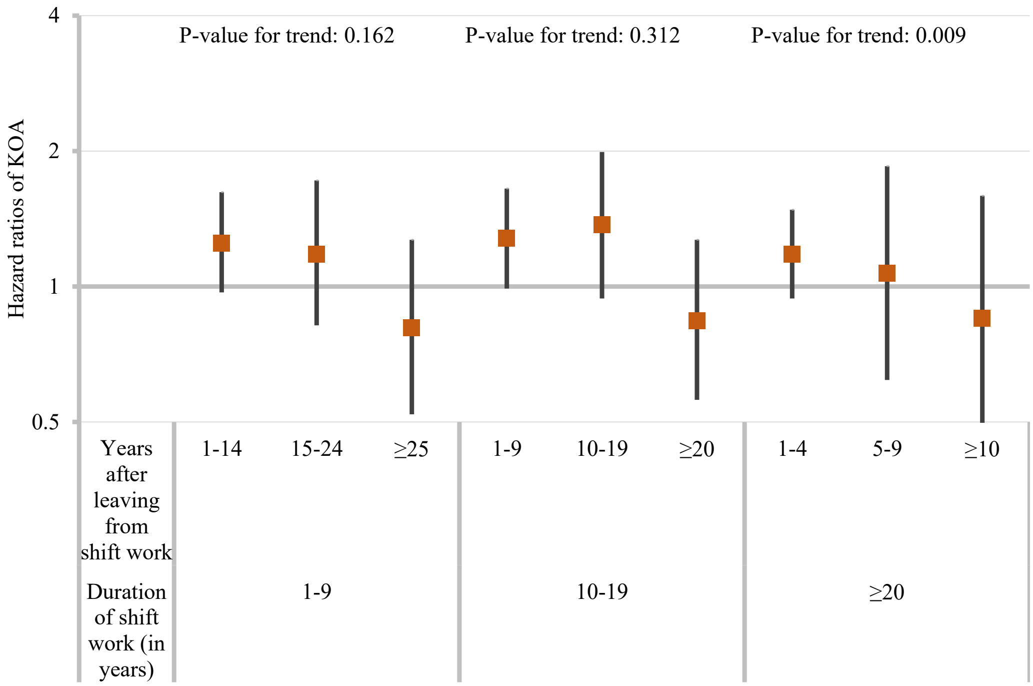

Figure 1. Hazard ratios for knee osteoarthritis (KOA) according to duration of shift work and the years after leaving shift work, compared to daytime workers. The model was adjusted for age, gender body mass index (continuous), smoking status, drinking status, physical exercise, working years, and work posture. Tests of linear trend were conducted by including the median value for each duration level of leaving shift work as a continuous variable in the models.

in many countries (28). An increased risk of KOA among shift workers in this study has indicated that the adverse health effects of shift work were diverse. Considering the increasing prevalence and burden of KOA, and the significant reduction in quality of life and work productivity induced by KOA (11, 29), further action should be carried out to avoid or regulate shift work.

Although the mechanisms for the increased risk of KOA due to shift work remain unclear, several factors may be underlying in this association. First, the circadian clock regulates various rhythmic biological processes, including wake-sleep cycles, cell cycles, energy metabolism, and hormone secretion. Shift work is generally associated with chronic circadian clock misalignment (30). This circadian misalignment directly disturbs the homeostasis of cartilage, bone, and tendons (31–33). Circadian misalignment has also been found to result in metabolic disorders and inflammatory consequences (34, 35), which have been linked to cartilage and bone homoeostasis (36). Second, shift work may influence KOA through sleep quality. In our previous reports, shift work was associated with reduced sleep quality (37). We further analyzed the mediating role of sleep quality in the relationship between shift work and KOA and found that poor sleep quality significantly mediated the total effects of shift work on KOA by 15.84%. Poor sleep may directly reduce the recovery time of knee problems. Third, shift workers tended to have different dietary habits from daytime workers, ie, greater energy density, increased saturated fat, and decreased dietary fiber were reported among shift workers (38, 39). A high intake of fat and saturated fatty acids was associated with the onset and progression of KOA, while dietary fiber was inversely associated with KOA worsening (40, 41).

Furthermore, our findings also suggested that the effect of shift work on the risk of KOA could decrease after leaving shift work. The risk of KOA may return to the daytime worker level after 25 years of ceasing shift work for participants that had ever been engaged in 1–9 years of shift work, while it took 20 years for those with 10–19 years of shift work, and it was reported to take <5 years for those with ≥20 years of shift work. These results suggest that the first few years could be the most critical time for shift workers to adapt themselves to irregular circadian clocks.

The strengths of this study include the large sample size, detailed occupational history, and detailed information on a wide range of potential confounders. We are aware of the limitations of this study. First, we did not provide knee X-ray examinations for each participant although they could have a free one if they had knee symptoms and the company was willing pay for such examinations. Second, information regarding shift work was self-reported, which may lead to misclassifications of the exposure. However, we checked the shift work information (yes/no) used in the present study with data collected in 2008, and the agreement (kappa coefficient) was 0.76 (95% CI 0.75–0.78). Third, although information regarding lifestyle was collected over the past year, the individuals may have changed their lifestyle over time. Fourth, we failed to include retired workers who died before the 2013 recruitment or moved to other cities, and this may have caused selection bias. But according to company records, 87% of retired employees attended this medical examination.

In conclusion, the present study showed that shift work was independently associated with an elevated risk of KOA. These findings have substantial implications for preventing KOA by modifying shift work policies.

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Disclosure of interest

The authors declare no conflicts of interest.

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