Leisure-time, occupational, and commuting physical activity and the risk of chronic kidney disease in a working population: a prospective cohort study

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Abstract

Background:

Very few attempts have been made to examine the association of leisure-time physical activity with chronic kidney disease (CKD) onset. In addition, there is no prospective information on the relationship between other domains of physical activity and CKD. In this study, we examined the risk of CKD in the context of leisure-time, occupational, and commuting physical activity.

Methods:

This prospective cohort study included 17,331 Japanese workers (aged 20–65 years at baseline) without CKD who were followed from 2006 to 2020. Leisure-time, occupational physical activity, and the duration of walking to and from work were assessed by a questionnaire at baseline. Incident CKD was defined as estimated glomerular filtration rate < 60 mL/min/1.73 m^2 and/or proteinuria [1+, 2+, or 3+] by dipstick. Cox proportional hazard regression models were used to estimate the hazard ratios (HRs) and 95% confidence intervals (CIs) of CKD.

Results:

During 147,752 person-years of follow-up, 4,013 participants developed CKD. After controlling for a wide range of covariates, leisure-time physical activity and walking for commute were not associated with CKD onset. By contrast, compared to the participants mostly engaging in sedentary work, those with standing/walking and fairly active work had HRs of 0.86 (95% CI: 0.79–0.94) and 0.87 (95%CI: 0.76-1.00) to develop CKD, respectively, after adjusting for all covariates including the other forms of physical activity (p for trend = 0.01).

Conclusions:

Occupational physical activity was associated with the risk of CKD, and leisure-time and commuting physical activity were not.

Background

Chronic kidney disease (CKD) is an increasing clinical and public health problem; it is a precursor for end-stage renal disease and a strong risk factor for cardiovascular morbidity and mortality [1, 2]. In 2017, the global prevalence of CKD was 9.1%, equivalent to approximately 700 million cases [1]. Few effective cure is available to treat patients with CKD; thus, the focus has been on the prevention of CKD incidence [3, 4]. Thus far, the literature has revealed that CKD shares several established risk factors (i.e., diabetes, hypertension, and obesity) with cardiovascular diseases [5].

Physical activity is another important factor known to reduce cardiovascular risk [6] and is hypothesized to be an important modifiable risk factor in the development of CKD, either directly or indirectly through favorable effects on diabetes, hypertension, and obesity [7, 8]. Although physical inactivity has been reported as a risk factor of CKD in several cross-sectional studies [9–12], evidence from prospective studies has been limited and inconsistent [10, 11, 13]. The Australian Diabetes, Obesity, and Lifestyle (AusDiab) Study and the Health, Aging, and Body Composition (Health ABC) study have demonstrated that physical activity was not associated with risk of incident CKD [10, 11]. By contrast, in a Taiwan cohort, a higher level of habitual physical activity was found to be associated with a lower risk of developing CKD [13].

In addition to the inconsistency in the association between physical activity and CKD, several other issues have not been addressed. First, cohort studies have focused on leisure-time physical activity alone or total physical activity (i.e., a combination of leisure-time and occupational physical activity) [10, 11, 13], but there is no evidence for the association in relation to other domains of physical activity, such as occupational or commuting physical activity. For a considerable fraction of the general population, work constitutes the main setting for physical activity [14]. Thus, the importance of work-related physical activity for CKD risk should be clarified in this population. Second, it remains unknown whether the physical activity–CKD association differs according to health status that proposed as increasing the risk of CKD (i.e., diabetes, hypertension, or obesity). Such data are essential for revealing the biological interaction between physical activity and these health conditions concerning CKD onset. Last, according to our review of the literature, this study is the first to report on this issue based on prospective cohort studies in the Japanese population, which has one of the highest prevalence of CKD [15, 16] and insufficient rates of physical activity.

To address these issues, we prospectively investigated the associations of leisure-time, occupational, and commuting physical activity with the risk of incidence of CKD in a large-scale cohort of the Japanese working population. We also analyzed the potential effect modification by a particular disease or condition or the other domains of physical activity based on the relation between 3 domains of physical activity and CKD.

Methods

Study design

This study was conducted as a part of the Japan Epidemiology Collaboration on Occupational Health (J-ECOH) Study, an ongoing large-scale cohort study among workers from multiple industries in Japan. The details of the J-ECOH Study and this study cohort have been described elsewhere [17, 18]. This analysis included data from one of the participating industries in the J-ECOH Study (electrical machinery and apparatus manufacturing), where detailed information on physical activity has been collected as a part of periodic health check-ups since 2006.

The study protocol was approved by the Ethics Committee of the National Center for Global Health and Medicine, Japan. The purpose and procedure of the J-ECOH Study were announced by using posters. Participants were allowed to refuse the provision of their data to the study. This procedure conforms to the Japanese Ethical Guidelines for Epidemiological Research for observational studies that use existing data.

Participants

In Japan, employers are obliged to organize health check-ups for their employees at least once per year under the Industrial Safety and Health Act. A total of 23,248 workers aged 20 to 65 years received health check-ups (comprehensive type) between April 2006 and March 2007 (baseline period) and had data for serum creatinine. We excluded workers with CKD (defined as an estimated glomerular filtration rate [eGFR] of < 60 mL/min/1.73 m^2 and/or proteinuria [+, 2+, or 3+ on dipstick [19]]; n = 1,510); with self-reported cancer (n = 179); with an eGFR of ≥200 mL/min/1.73m^2 (due to possible measurement errors[20]; n = 5); with incomplete information on physical activity (n = 2,424); and with engagement in an unspecified activity only during leisure (n = 489). We further excluded workers who attended no subsequent health check-ups or who had no measurement of eGFR or proteinuria in a subsequent health check-up (n = 1,973). Finally, 17,331 participants (15,544 men and 1,787 women) were included in the analyses (Figure S1).

Assessment of physical activity during leisure, commuting, and work

Details of the information collected for leisure-time physical activity have been described in the literature [18, 21, 22]. Participants were asked to choose up to 3 activities among a list of 20 exercise or sports activities and the frequency (times per month) and duration of time per occasion (minutes) for each activity. If participants engaged in activities not listed in the questionnaire, they were instructed to choose an activity of similar intensity from the list. Of the 20 exercise or sports activities in the list, one activity named "Other" was not used for further analysis.

The metabolic equivalent (MET; 1 MET=1 kcal per h per kg of body weight) value for each activity was determined according to Ainsworth's compendium of physical activities [23]. Of the 19 activities, 12 (*walking not for work or commuting*, *walking fast not for work or commuting*, *golf practice*, *golf*, *baseball*, *softball*, *bike cycling*, *table tennis*, *pang pong*, *badminton*, *muscle strength training*, and *radio gymnastics*) were classified as moderate activities (3 to 5.9 MET), and 7 (*light jogging [approximately 6 min/km]*, *jogging*, *swimming*, *soccer*, *tennis*, *aerobics*, and *jump rope*) were classified as vigorous activities (≥6 MET). Leisure-time physical activity was defined as the product of intensity (MET) and duration of exercise (h), and the calculated MET-h per week of each individual was placed into one of the 4 categories—inactive (0 MET-h), low (>0 to <7.5 MET-h), moderate (≥7.5 to <16.5 MET-h), or high (≥16.5 MET-h)—which roughly accords with the classification of current physical activity guideline [24].

Occupational physical activity was assessed by the question *To what extent is your work physically demanding?* with the following response options: *mostly sedentary*, *mostly standing*, *walking often*, or *fairly active*. We combined the 2 categories in the middle (i.e., mostly standing and often walking) to increase the statistical power.

Commuting physical activity was assessed by the self-reported duration of walking to and from work (in minutes) and categorized as <20, 20 to <40, and ≥40 min for the analysis, which is similar to categories in other studies in Japan [18, 25].

Ascertainment of chronic kidney disease cases

CKD was assessed by using the data of annual health check-ups from baseline to March 2019 and defined as an eGFR of < 60 mL/min/1.73 m^2 and/or proteinuria (+, 2+, or 3+ on dipstick) [19]. eGFR was calculated by using the following formula established by the working group of the Japanese CKD Initiative: eGFR (mL/min/1.73 m^2) = 1.94 × (serum creatinine)$^{-1.094}$ × (age)$^{-0.287}$ × (0.739 if female) [26]. Serum creatinine was measured by the enzyme method with an autoanalyzer (Hitachi 7600, Japan). Proteinuria was tested by dipsticks and by using an autoanalyzer (Siemens Healthcare, Japan) and categorized as negative, ±, 1+, 2+, and 3+ (corresponding to protein levels of undetectable, trace, 30 mg/dL, 100 mg/dL, and ≥300 mg/dL, respectively). The date of check-up when CKD was first identified was the incidence date of CKD.

Covariates

The covariates included eGFR, age, sex, smoking status, alcohol consumption, job position, overtime work, shift work, commuting mode, and sleep duration, hypertension, diabetes, history of cardiovascular disease, dyslipidemia, hyperuricemia, and body mass index (BMI) at baseline. We refer to the online Supplementary Appendix 1 for data collection methods, which have been described in previous papers [18, 22, 27].

Statistical analysis

We calculated person-years of follow-up for each participant, from the date of the baseline health check-up to the date of health check-up when the CKD was first identified or the date of the last health check-up, whichever came first. We ran a Cox proportional hazards regression to calculate hazard ratios (HRs) and 95% confidence intervals (CIs) for the association between leisure-time, occupational, and commuting physical activity and time to incident CKD. We adjusted for covariates in a stepwise manner.

Model 1 included baseline eGFR, age (continuous, years), and sex. Model 2 additionally adjusted for smoking status (never, former, or current), alcohol consumption (0, >0 to <2, or ≥2go/day), job position (high or low), overtime work (<45, 45 to <60, 60 to <80, 80 to <100, or ≥100 h/month), shift work (yes or no), primary commuting mode (walking, bicycling, train/bus, or car/motorbike), and sleep duration (<5, 5 to<6, 6 to<7, or ≥7 h per day). Model 3 further adjusted for potential mediators, such as hypertension, diabetes, history of cardiovascular disease, dyslipidemia, hyperuricemia, and BMI (<18.5, 18.5 to <25.0, 25.0 to <30.0, or ≥30.0 kg/m^2). Model 4 adjusted for other types of physical activity, which were mutually adjusted.

The trend association between leisure-time physical activity and risk of CKD was assessed by assigning the median dose of leisure-time physical activity in each category and treating this variable as continuous. For the trend for occupational physical activity, we assigned a score of 1–3 to sedentary work, walking or standing during work, and fairly active during work, respectively. For commuting physical activity, we assigned 10, 30, and 50 min to increasing categories of walking to and from work (<20, 20 to <40, and ≥40 min). We also conducted sensitivity analyses and excluded participants with <2 years of follow-up term for the aforementioned major analyses.

To test the effect modification by hypertension, diabetes, obesity (BMI<25 or ≥25 kg/m^2), baseline eGFR (60 to 89 or ≥90 mL/min/1.73 m^2), occupational (sedentary work or not), and commuting physical activity (<20 or ≥20 min), we conducted subgroup analyses in a fully adjusted model (model 4). Those subgroup analyses were repeated between occupational or commuting physical activity and CKD onset. The proportional hazards assumption was examined using Schoenfeld residuals, and all covariates agreed with the proportional hypothesis except for age and baseline eGFR.

The proportion of missing data for each covariate was as follows: smoking status (0.4%), job position (3.3%), monthly overtime work (3.6%), shiftwork (2.9%), primary commuting mode (0.1%), sleep duration (0.2%), diabetes (0.2%), dyslipidemia (0.02%), and hyperuricemia (0.04%). We performed multiple imputations by using the chained equation method, with multinomial logistic regression for imputation of smoking status, monthly overtime work, primary commuting mode, and sleep duration; and logistic regression for job position, shiftwork, diabetes, dyslipidemia, and hyperuricemia. The imputation used all the variables involved in all the analytic models, including the outcome variables of time-to-event and event status. The 20 imputed data sets were generated, and the results were combined by using Rubin's rules. All statistical analyses were performed with Stata/MP version 16.1 (Stata Corp., College Station, Texas). The statistical significance was set at a 2-sided P value of 0.05 for all analyses.

Results

At baseline, the mean (standard deviation) age of the 17,331 participants was 42.8 (10.0) years, and 90% were men; 65% of the participants were physically inactive during leisure, and 54% were sedentary during work. Table 1 shows the characteristics of the study population by baseline leisure-time physical activity categories. The proportions of men and those with diabetes were higher among participants with higher leisure-time physical activity. By contrast, the level of baseline eGFR and the ratios of the current smoker and long overtime work decreased with increasing leisure-time physical activity. The baseline characteristics stratified by occupational or commuting physical activity are presented in Table S1-2.

Table 1
Baseline characteristics of the participants, according to the volume of leisure-time physical activity

	Leisure-time physical activity (MET-h/week)			
	Inactive (0 MET-h/week)	Low (> 0 to < 7.5 MET-h/week)	Moderate (7.5 to < 16.5 MET-h/week)	High (≥ 16.5 MET-h/week)
Participants	n = 11,170	n = 2,896	n = 1,901	n = 1364
Male sex, n (%)	9,826 (88.0)	2,669 (92.2)	1,763 (92.7)	1,286 (94.3)
Age, years	42.7 (9.8)	42.2 (10.0)	43.1 (10.3)	43.6 (10.9)
eGFR, mL/min/1.73 m^2	89.1 (16.1)	87.3 (15.1)	85.9 (15.1)	85.8 (14.9)
BMI, kg/m^2	23.4 (3.5)	23.6 (3.4)	23.8 (3.2)	23.6 (3.1)
Smoking status, n (%)				
Never	3,793 (34.0)	998 (34.5)	648 (34.1)	509 (37.3)
Former	1,918 (17.2)	593 (20.5)	458 (24.1)	316 (23.2)
Current	5,407 (48.4)	1,298 (44.8)	791 (41.6)	537 (39.4)
Alcohol intake, n (%)				
None	3,682 (33.0)	774 (26.7)	504 (26.5)	353 (25.9)
> 0 to < 2 go/day	5,099 (45.6)	1,513 (52.2)	955 (50.2)	673 (49.3)
≥ 2 go/day	2,389 (21.4)	609 (21.0)	442 (23.3)	338 (24.8)
High job position, n (%)	1,788 (16.0)	536 (18.5)	418 (22.0)	257 (18.8)
Long overtime work (≥ 45 h/month)	4,000 (35.8)	1,033 (35.7)	647 (34.0)	410 (30.1)
Shift work, n (%)	2,929 (26.2)	723 (25.0)	426 (22.4)	328 (24.0)
Commuting mode, n (%)				
Walking	1,578 (14.1)	392 (13.5)	257 (13.5)	191 (14.0)
Cycling	655 (5.9)	175 (6.0)	126 (6.6)	94 (6.9)
Bus/train (public transportation)	2,439 (21.8)	596 (20.6)	359 (18.9)	234 (17.2)
Car/motorbike	6,490 (58.1)	1,731 (59.8)	1,159 (61.0)	844 (61.9)
Sleep duration of < 6 h/day, n (%)	5,708 (51.1)	1,361 (47.0)	910 (47.9)	620 (45.5)
Hypertension, n (%)	1,489 (13.3)	364 (12.6)	255 (13.4)	186 (13.6)
Diabetes, n (%)	802 (7.2)	242 (8.4)	173 (9.1)	123 (9.0)
History of CVD, n (%)	65 (0.6)	16 (0.6)	16 (0.8)	9 (0.7)
Dyslipidemia, n (%)	5,111 (45.8)	1,274 (44.0)	837 (44.0)	522 (38.3)

Leisure-time physical activity (MET-h/week)				
Hyperuricemia, n (%)	2,218 (19.9)	596 (20.6)	388 (20.4)	262 (19.2)
Walking to and from work, n (%)				
0 to < 20 min	5,979 (53.5)	1,547 (53.4)	1,070 (56.3)	786 (57.6)
20 to < 40 min	3,557 (31.8)	912 (31.5)	543 (28.6)	405 (29.7)
≥ 40 min	1,634 (14.6)	437 (15.1)	288 (15.1)	173 (12.7)
Occupational physical activity, n (%)				
Sedentary	5,867 (52.5)	1,604 (55.4)	1,130 (59.4)	726 (53.2)
Standing or walking	4,095 (36.7)	989 (34.2)	594 (31.2)	472 (34.6)
Fairly active	1,208 (10.8)	303 (10.5)	177 (9.3)	166 (12.2)

Data are shown as the mean (standard deviation) for continuous variables and as a number (percentages) for categorical variables. The proportion of missing data for each covariate was as follows: smoking status (0.4%), job position (3.3%), monthly overtime work (3.6%), shiftwork (2.9%), primary commuting mode (0.1%), sleep duration (0.2%), diabetes (0.2%), dyslipidemia (0.02%), and hyperuricemia (0.04%).

BMI, body mass index; CVD, cardiovascular disease; eGFR, estimated glomerular filtration rate.

During 147,752 person-years of follow-up, 4,013 (23%) participants developed CKD, with an overall incidence rate of 27.2 cases per 1,000 person-years. The median follow-up was 10.6 years (range 0.2–13.0). Table 2 shows the associations of leisure-time, occupational, and commuting physical activity with incident CKD. Leisure-time physical activity was not significantly related to the risk of developing CKD in any adjusted models. By contrast, occupational physical activity was observed as a significant association in all models.

Table 2
Hazard ratios of chronic kidney disease, according to leisure-time, occupational, and commuting physical activity.

	Cases/Subjects	Person-years	Model 1 [b]	Model 2 [c]	Model 3 [d]	Model 4 [e]
Leisure-time physical activity						
Inactive (0 MET-h/week)	2,557/11,170	94,647	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Low (> 0 to < 7.5 MET-h/week)	643/2,896	25,572	0.92 (0.84-1.00)	0.93 (0.85–1.02)	0.94 (0.86–1.03)	0.94 (0.86–1.03)
Moderate (7.5 to < 16.5 MET-h/week)	474/1,901	16,116	1.04 (0.94–1.15)	1.06 (0.96–1.17)	1.06 (0.96–1.17)	1.06 (0.96–1.17)
High (≥ 16.5 MET-h/week)	339/1,364	11,417	1.04 (0.92–1.16)	1.05 (0.94–1.18)	1.08 (0.96–1.21)	1.08 (0.96–1.21)
		P for trend [a]	0.402	0.224	0.118	0.116
Occupational physical activity						
Sedentary	2,403/9,327	79,584	**1.00 (reference)**	**1.00 (reference)**	**1.00 (reference)**	**1.00 (reference)**
Standing/Walking	1,246/6,150	51,974	**0.88 (0.82–0.94)**	**0.87 (0.80–0.94)**	**0.88 (0.82–0.95)**	**0.88 (0.86–0.96)**
Fairly active	364/1,854	16,194	**0.88 (0.79–0.98)**	**0.87 (0.77–0.99)**	**0.91 (0.81–1.03)**	**0.91 (0.81–1.03)**
		P for trend [a]	**< 0.001**	**0.001**	**0.012**	**0.012**
Walking for commuting to and from work						
< 20 min	2,013/9,382	80,581	**1.00 (reference)**	1.00 (reference)	1.00 (reference)	1.00 (reference)
20 to < 40 min	1,334/5,417	46,106	**1.10 (1.03–1.18)**	1.06 (0.98–1.15)	1.06 (0.98–1.15)	1.06 (0.98–1.15)
≥ 40 min	666/2,532	21,066	**1.14 (1.04–1.25)**	1.07 (0.97–1.20)	1.09 (0.98–1.21)	1.09 (0.98–1.21)
		P for trend [a]	**0.001**	0.124	0.091	0.093

	Cases/Subjects	Person-years	Model 1 [b]	Model 2 [c]	Model 3 [d]	Model 4 [e]

Data are shown as the hazard ratio (95% confidence interval).

[a] *P* value for the linear trend was calculated by using the Cox proportional hazards regression and assigning each category of physical activity as a continuous variable.

[b] Model 1 was adjusted for baseline estimated glomerular filtration rate (60 to 89 or ≥ 90 mL/min/1.73 m^2), age (continuous), and sex.

[c] Model 2 was further adjusted for baseline smoking status (never, former, or current), alcohol consumption (0, > 0 to < 2, or ≥ 2go/day), job position (high or low), overtime work (< 45, 45 to < 60, 60 to < 80, 80 to < 100, or ≥ 100 h), shift work (yes or no), commuting mode (walking, bicycling, train/bus, or car/motorbike), and sleep duration (< 5, 5 to < 6, 6 to < 7, or ≥ 7 h per day).

[d] Model 3 was further adjusted for potential mediators, including baseline hypertension, diabetes, history of cardiovascular disease, dyslipidemia, hyperuricemia, and body mass index (< 18.5, 18.5 to < 25.0, 25.0 to < 30.0, or ≥ 30.0 kg/m^2).

[e] Model 4 was further adjusted for the other types of physical activity (i.e., leisure-time physical activity (0, > 0 to < 7.5, 7.5 to < 16.5, or ≥ 16.5 MET-h/week), occupational physical activity (sedentary, standing or walking, and fairly physically activity), or walking for commuting to and from work (< 20 min, 20 to < 40 min, or ≥ 40 min]).

Relative to the participants who were sedentary during work, those who were standing or walking and fairly active during work had HRs of 0.88 (95% CI: 0.82–0.95) and 0.91 (0.81–1.03), respectively, after adjustment of potential mediators in Model 3 (p for trend 0.012). The association was virtually unchanged after additional adjustment for the other domains of physical activity (Model 4). Walking for commuting to and from work was significantly associated with CKD in Model 1 (adjusted for age, sex, baseline eGFR); however, the association was no longer statistically significant after adjustment of other covariates (Models 2–4). In the sensitivity analyses excluding participants with < 2 years follow-up (1,550 participants, including 824 incident cases), the associations virtually did not change. That is, sedentary during work remained a significant association with CKD risk (Table S3).

Subgroup analyses of leisure-time physical activity (Table 3) showed that the interactions by hypertension, diabetes, obesity, and baseline kidney function were not statistically significant (p for interaction > 0.05). Additionally, the HRs associated with leisure-time physical activity did not differ across subgroups of other domains of physical activity, defined by occupational physical activity (sedentary or active during work) or commuting (< 20 min or ≥ 20 min for walking to and from work). Regarding the subgroup analyses of occupational and commuting physical activity, the interactions with other forms of physical activity were null results (Tables S4 and S5).

Table 3
Hazard ratios of chronic kidney disease according to the volume of leisure-time physical activity in subgroups.

Subgroups	Cases/Subjects	Person-years	Leisure-time physical activity (MET-h/week)				*P* for interaction
			Inactive (0 MET-h/week)	Low (> 0 to < 7.5 MET-h/week)	Moderate (7.5 to < 16.5 MET-h/week)	High (≥ 16.5 MET-h/week)	
Hypertension							
Yes	799/2,294	15,989	1.00 (Reference)	0.92 (0.78–1.13)	0.96 (0.77–1.19)	0.81 (0.61–1.07)	0.077
No	3,214/15,037	131,764	1.00 (Reference)	0.91 (0.83-1.00)	1.04 (0.93–1.17)	1.12 (0.99–1.27)	
Diabetes							
Yes	458/1,340	9,338	1.00 (Reference)	0.95 (0.74–1.23)	1.34 (1.02–1.75)	0.80 (0.55–1.16)	0.161
No	3,543/15,956	138,141	1.00 (Reference)	0.93 (0.85–1.03)	1.02 (0.91–1.13)	1.13 (1.00-1.28)	
Obesity							
BMI ≥ 25 kg/m^2	1,541/5,054	41,180	1.00 (Reference)	0.88 (0.76–1.01)	1.05 (0.90–1.23)	0.97 (0.80–1.18)	0.136
BMI < 25 kg/m^2	2,472/12,277	106,572	1.00 (Reference)	0.97 (0.87–1.08)	1.06 (0.93–1.20)	1.15 (1.00-1.32)	
Baseline eGFR							
60 to 89 mL/min/1.73 m^2	2,843/10,248	84,227	1.00 (Reference)	0.92 (0.83–1.02)	1.07 (0.96–1.20)	1.11 (0.98–1.27)	0.190
≥ 90 mL/min/1.73 m^2	1,170/7,083	63,525	1.00 (Reference)	0.98 (0.83–1.14)	1.04 (0.85–1.27)	0.93 (0.73–1.18)	
Occupational physical activity							
Sedentary	2,403/9,327	79,584	1.00 (Reference)	1.01 (0.90–1.12)	1.14 (1.00-1.29)	1.07 (0.92–1.24)	0.424
Active [a]	1,610/8,004	68,168	1.00 (Reference)	0.84 (0.73–0.97)	0.91 (0.77–1.09)	1.08 (0.91–1.29)	
Walking to and from work							
< 20 min	2,013/9,382	80,581	1.00 (Reference)	0.92 (0.81–1.04)	1.09 (0.95–1.25)	1.10 (0.95–1.08)	0.586

Subgroups	Cases/Subjects	Person-years	Leisure-time physical activity (MET-h/week)				*P* for interaction
			Inactive (0 MET-h/week)	Low (> 0 to < 7.5 MET-h/week)	Moderate (7.5 to < 16.5 MET-h/week)	High (≥ 16.5 MET-h/week)	
≥ 20 min	2,000/7,949	67,171	1.00 (Reference)	0.96 (0.85–1.08)	1.03 (0.89–1.19)	1.05 (0.89–1.25)	

Data are shown as the hazard ratio (95% confidence interval).

BMI, body mass index.

[a] Active including standing, walking, and fairly active at work.

The Cox proportional hazards regression adjusted for baseline age (continuous), sex, smoking status (never, former, or current), alcohol consumption (0, > 0 to < 2, or ≥ 2go/day), job position (high or low), overtime work (< 45, 45 to < 60, 60 to < 80, 80 to < 100, or ≥ 100 h), shift work (yes or no), primary commuting mode (walking, bicycling, train/bus, or car/motorbike), sleep duration (< 5, 5 to < 6, 6 to < 7, or ≥ 7 h per day), hypertension, diabetes, history of cardiovascular disease, dyslipidemia, hyperuricemia, body mass index (< 18.5, 18.5 to < 25.0, 25.0 to < 30.0, or ≥ 30.0 kg/m2), baseline estimated glomerular filtration rate (60–89 or ≥ 90 mL/min/1.73 m^2), leisure-time physical activity (0, > 0 to < 7.5, 7.5 to < 16.5, or ≥ 16.5 MET-h/week), occupational physical activity (sedentary, standing or walking, and fairly physically activity), and walking for commuting to and from work (< 20 min, 20 to < 40 min, or ≥ 40 min).

Discussion

In this large-scale Japanese working population, higher leisure-time physical activity and longer walking time during commuting were not associated with the risk of incident CKD. By contrast, we found that engaging in sedentary work was significantly associated with a higher risk of developing CKD. The non-significant association between leisure-time and commuting physical activity and incident CKD was observed across several subgroups defined by baseline characteristics, and the other forms of physical activity. According to our review of the literature, this is the first prospective study to examine the association between physical activity and CKD onset in the working population while assessing differential effects by leisure-time, occupational, and commuting physical activity.

The finding in this study of no significant association between leisure-time physical activity and incident CKD agrees with other studies in Australia [10] and the United States [11, 28] For example, the AusDiab Study of 6,318 Australian adults showed that inactive (0 min/week) and insufficiently active (< 150 min/week) leisure were not associated with a higher risk of CKD onset compared to sufficiently active (≥ 150 min/week) [10]. By contrast, a more recent Taiwanese cohort study among 190,074 adults [13] reported a significant, albeit modest, reduction in CKD incident associated with leisure-time physical activity; compared to workers with very low leisure-time physical activity, HRs for low, moderate, and high leisure-time physical activity were 0.93 (95%CI 0.88–0.98), 0.94 (95%CI 0.89–0.99), and 0.91 (95%CI 0.85–0.96), respectively. Given this small size of risk reduction and no clear dose-response relationship in the Taiwanese cohort, together with no association in other prospective studies, the epidemiological evidence has not supported a significant protective role of leisure-time physical activity against CKD.

Our analysis regarding occupational physical activity showed that engaging in sedentary work was significantly associated with an increase in the risk of CKD. Being sedentary during work is typical sedentary behavior in daily life, along with, for example, sitting in a chair and watching television, playing video games playing, or reading [29]. Our findings are supported by limited evidence. In a cross-sectional study of male employees in Northern Ireland, a longer time spent sitting at work was inversely associated with eGFR, and more time spent carrying objects or being active at work was positively related to eGFR [30]. Additionally, the Health ABC study showed that prolonged television watching (> 3 hours/day) was associated with a faster decline in kidney function and a higher incidence of CKD in older adults [11]. Prolonged sitting time has been linked to the unfavorable profile of insulin sensitivity, inflammation, and lipid metabolism, independent of whether individuals fulfill physical activity guidelines [31, 32]. Because of the scarce prospective evidence on the association between occupational physical activity and development of CKD, additional cohort studies are necessary to determine if engaging sedentary work is associated with a higher risk of CKD.

We observed no association between the duration of walking on commuting to and from work and CKD incident in the participants and among the participants engaging in sedentary work (Table S5). By contrast, the cross-sectional study in Northern Ireland showed better renal function was associated with higher physical activity while commuting to or from work [30]. In that study, commuting physical activity was assessed based on detailed information (intensity, frequency, and duration) and expressed in MET-hours/week. Thus, further prospective studies with a detailed assessment of commuting physical activity are necessary.

This study has several strengths, for example, the large size of the cohort, long-term follow-up, and annual assessments with data on serum creatinine and proteinuria. In addition, we adjusted for comprehensive covariates, including sleep duration and work-related factors, which the literature had not considered.

However, several of this study's limitations warrant mention. First, physical activity was assessed with unvalidated self-reported questionnaires. Nonetheless, the questionnaires used in our study are similar to previously validated and reproducible questionnaires for leisure, occupational, and commuting activities [33–35]. Second, we used only baseline information on physical activity, and the non-differential misclassification in physical activity due to within-individual variability during follow-up would lead the results toward the null. Third, residual confounding and unmeasured confounders, such as diet, might have affected the risk of CKD. Finally, we defined an incident of CKD by using a single point measurement of eGFR and/or proteinuria. Thus, because the clinical diagnosis of CKD is determined based on 2 measures taken at least 3 months apart [19], our criteria for CKD has a sensitivity of 100% but low specificity, distorting the associations toward the null.

Conclusions

We demonstrated that leisure-time and commuting physical activity were not associated with the development of CKD in this large-scale working population and that engaging in sedentary work was related to the risk of CKD incident.

Abbreviations

BMI: body mass index; CI: confidence interval; CKD: Chronic kidney disease; CVD: cardiovascular disease; eGFR: estimated glomerular filtration rate; HR: hazard ratio; J-ECOH: Japan Epidemiology Collaboration on Occupational Health; MET: metabolic equivalent.

Declarations

Ethics approval and consent to participate

The study protocol was approved by the Ethics Committee of the National Center for Global Health and Medicine, Japan. The purpose and procedure of the J-ECOH Study were announced by using posters. Participants were allowed to refuse the provision of their data to the study. This procedure conforms to the Japanese Ethical Guidelines for Epidemiological Research for observational studies that use existing data.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated and/or analysed during the current study are not publicly available due ethical restrictions and participant confidentiality concerns, but de-identified data are available from Dr. Mizoue (Department of Epidemiology and Prevention, Center for Clinical Sciences, National Center for Global Health and Medicine, Tokyo, Japan) to qualified researchers on reasonable request.

Competing interests

The authors declared no conflict of interest. T.N., T Honda, Shuichiro Y, and T Hayashi are occupational physicians in the participating company.

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Authors' contributions

Research idea and study design: Shohei Y; data acquisition: TN, T Honda, Shuichiro Y, and T Hayashi; data analysis/interpretation: Shohei Y, YI, KK, TM, and TM; statistical analysis: Shohei Y; supervision or mentorship: YI, KK, and TM. Each author contributed important intellectual content during manuscript drafting or revision, accepts personal accountability for the author's own contributions, and agrees to ensure that questions pertaining to the accuracy or integrity of any portion of the work are appropriately investigated and resolved.

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