Original article

Scand J Work Environ Health. 2015;41(6):519–528. doi:10.5271/sjweh.3526

Occupational sitting time and risk of all-cause mortality among Japanese workers

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Kikuchi H, Inoue S, Odagiri Y, Inoue M, Sawada N, Tsugane S. Occupational sitting time and risk of all-cause mortality among Japanese workers. *Scand J Work Environ Health.* 2015;41(6):519–528. doi:10.5271/sjweh.3526

Objectives Prolonged sitting is a health risk for cardiovascular diseases and all-cause mortality, independent of moderate-to-vigorous physical activity. Epidemiological evaluation of occupational sitting has received little attention, even though it may have a potential impact on workers' health. We prospectively examined the association between occupational sitting time and all-cause mortality.

Methods Community-dwelling, Japanese workers aged 50–74 years who responded to a questionnaire in 2000–2003 were followed for all-cause mortality through 2011. Cox proportional hazard models were employed to calculate hazard ratios (HR) of all-cause mortality among middle (1–<3 hours/day) or longer (≥3 hours/day) occupationally sedentary subjects by gender or types of engaging industry ("primary industry" and "secondary or tertiary industry").

Results During 368 120 person-years of follow-up (average follow-up period, 10.1 years) for the 36 516 subjects, 2209 deaths were identified. Among workers in primary industry, longer duration of occupational sitting was significantly or marginally associated with higher mortality [HR 1.23, 95% confidence interval (95% CI) 1.00–1.51 among men; HR 1.34, 95% CI 0.97–1.84 among women]. No associations were found among secondary or tertiary industry workers (men: HR 0.87, 95% CI 0.75–1.01; women: HR 1.03, 95% CI 0.77–1.39).

Conclusions Occupational sitting time increased all-cause mortality among primary industry workers, however similar relationships were not observed for secondary-tertiary workers. Future studies are needed to confirm detailed dose–response relationships by using objective measures. In addition, studies using cause-specific mortality data would be important to clarify the physiological underlying mechanism.

Key terms Japan; occupational health; occupational injury; occupational illness; sedentary lifestyle.

Sedentary behaviors, defined as any waking behavior characterized by an energy expenditure <1.5 MET (multiples of the basal metabolic rate) while in a sitting or reclining posture, such as television viewing, computer use or car-driving (1), are associated with increased all-cause mortality as well as risks of cardiovascular disease and type 2 diabetes (2–4). Studies have shown relationships between prolonged sitting and poor health outcomes independent of moderate-to-vigorous physical activity (MVPA) (5). Decreasing sedentary behavior, in addition to increasing MVPA, is now considered an important strategy to reduce health risk (6, 7). Owen et al suggested that sedentary time mainly consists of four domains, ie, occupational, leisure time, transport-related, and domestic (7). In this context, many previous studies have focused on sedentary behavior in leisure time such as TV viewing time or screen time, rather than occupational sitting time (8–11).

Because occupational activities are generally determined not only by personal decision but also by job duties, chronic diseases related to "long and mandatory sitting at work" could be regarded as resulting from occupational

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exposure. Time spent in occupation generally accounts for a large part of waking hours among workers (12). Given that more workers are in occupations that require prolonged sitting times, sitting while at work needs to be assessed in terms of its possible contribution to workers' health (13).

Uffelen et al showed in their review that previous longitudinal studies seeking an association between occupational sitting and all-cause mortality have been limited and have shown inconsistent results (14). However, not all studies reviewed by Uffelen focused on occupational sitting time, with some focusing on physical inactivity (15–19), which reflects insufficient levels of MVPA. The distinction between "physical inactivity" and "sedentary behaviors" is important (1). Those who engage in high amounts of sedentary behavior can be "active" in terms of satisfying physical activity guidelines, which recommend people do 30 minutes of MVPA per day (8, 20). In other words, too much sitting and too little MVPA represent separate and distinct risk factors for chronic, noncommunicable diseases (eg, cardiovascular disease, diabetes or cancer) (1).

In this context, longitudinal studies aimed at evaluating influences of occupational sitting time on mortality while adjusting for MVPA are needed. However, to the best of our knowledge there is only one study, conducted in Britain, showing a positive association between occupational sitting and mortality that has evaluated both occupational sitting and MVPA (19).

The purpose of this study was to assess the association between occupational sitting time and all-cause mortality, independently from MVPA, in a Japanese cohort study.

Methods

Study population

The Japan Public Health Centre-based prospective study (JPHC study) began in 1990–1994, comprising Cohort I (started in 1990), and Cohort II (started in 1993–1994). Detailed survey procedures are explained elsewhere (21). Briefly, it targeted all registered Japanese inhabitants in 11 public health center areas who were aged 40–69 years at the beginning of the baseline survey. The participants were informed of the objectives of the study, and those who completed the survey questionnaire were regarded as consenting to participate. This survey was conducted at baseline as well as at 5-year (second) and 10-year (third) follow-up sessions. The study protocol was approved by the institutional review board of the National Cancer Centre, Japan. Questions on occupational sitting and physical activity time were asked in the third survey only, thereby making this survey the starting point in the present study.

At baseline, 140 420 individuals were identified as being in the study population. After excluding 440 persons with non-Japanese nationality (N=51), duplicate enrolment (N=4), a late report of emigration occurring before the start of the baseline study (N=378), or ineligibility owing to an incorrect birth date (N=7), a population-based cohort of 139 980 individuals was established. After further excluding 13 952 persons who had died or moved out of Japan, 126 028 subjects remained. A total of 99 447 subjects responded to the 10-year follow-up questionnaire, yielding a response rate of 79%.

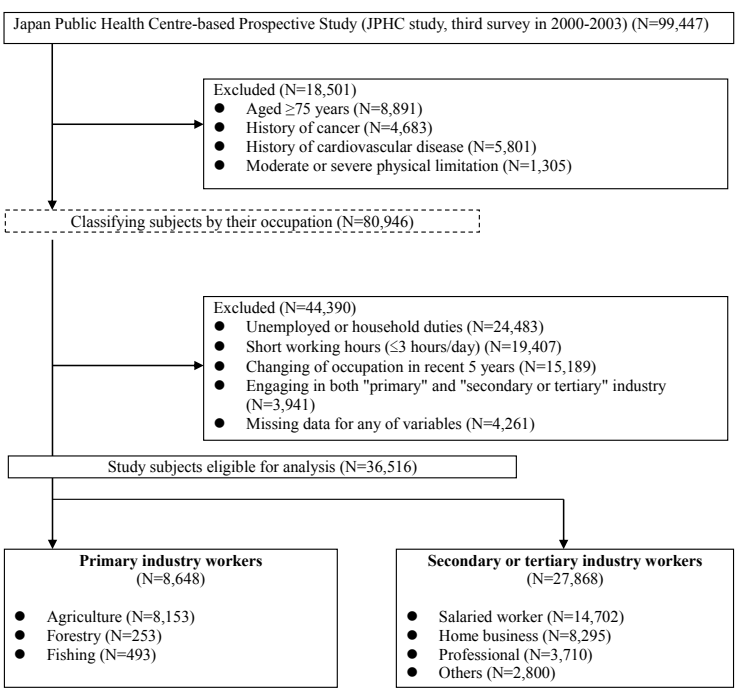

Figure 1. Flowchart of participants

Follow-up

Participants who responded to the 10-year follow-up questionnaire were followed from the starting point until December 31, 2011. Changes in residence status, including survival, were confirmed annually by residential registry. Information on the cause of death for deceased subjects was obtained from death certificates, provided by the Japanese Ministry of Health, Labor and Welfare with permission, in which the cause of death was defined according to the International Classification of Diseases, Tenth Revision (22). Registration of death is required by the Family Registration Law and is believed to be complete.

The flow of subjects is shown in figure 1. Because the social healthcare system is different for adults aged ≥75 years in Japan, we excluded subjects aged ≥75 years (N=8891). Subjects with a history of cancer (N=4683) or cardiovascular disease (N=5801) were also excluded.

Regarding physical limitation, participants were asked "How is your physical condition in daily life?" and given the following choices of answer: (i) no limitation; (ii) slight limitation, but they could drive vehicles or take public transportation alone; (iii) slight limitation, but they could walk around the neighborhood; (iv) partially limited, but they could go out with some assistance; (v) partially limited, and they seldom go out; (vi) moderately limited and they use a wheelchair, but they eat or evacuate by themselves; (vii) moderately limited and they need assistance to get into a wheelchair; (viii) severely limited and they lie in bed all day, but they can turn over by themselves; (ix) severely limited and they lie in bed all day, and they cannot turn over by themselves. Subjects who answered anywhere from (iii) to (ix) at the starting point were excluded (N=1305).

In addition, participants who were not presently employed or working in home duties only (N=24 483), and whose daily working hours were ≤3 hours (N=19 407) were excluded. For the purpose of investigating the impact of occupational exposure, we further excluded subjects who had changed their regular jobs within 5 years of data collection (N=15 189). Finally, participants who had missing information on any of the variables used in the present analysis (N=4261) were also excluded. Some participants had ≥2 conditions for exclusion. After exclusion, 36 516 participants (19 863 Japanese men and 16 653 Japanese women) were eligible for analysis.

Occupation categories

The self-administered questionnaire included four multiple-choice and short-answer questions specifically related to occupation and employment status. Participants were asked "What is your current occupation?" with the following possible answer choices: (i) agriculture; (ii) forestry; (iii) fishing; (iv) salaried worker; (v) home business; (vi) professional; (vii) household duties; (viii) unemployed.

The present study defined two categories in occupation. Farmers, forestry workers, and fishermen represented "primary industry", while salaried workers, home businesses, and professionals were defined as "secondary or tertiary industry". As stated above, respondents who answered home duties and/or unemployed only (N=24 483) were excluded from the present study (figure 1).

Measurement of occupational sitting and physical activity time

In our questionnaire, subjects were asked "How long do you spend in the following tasks at work?" with answer choices of "sitting tasks", "standing tasks", "walking tasks", and "strenuous tasks". Subjects were then asked the average duration of each task with the following options: (i) none; (ii) 0–<1; (iii) 1–<3; (iv) 3–<5; (v) 5–<7; (vi) 7–<9; (vii) 9–<11; (viii) >11 hours/day. For calculating sitting and MVPA time in occupation, the midpoint of the range for each category was assigned. When minimum and maximum values were presented on the questionnaire, boundary values were assigned in the highest or lowest categories.

Average time of occupational sitting time, walking at work, and strenuous work was determined by multiplying frequency and duration. Occupational sitting time was then categorized based on the tertile value: short (<1 hour/day), middle (1–<3 hours/day) or longer (≥3 hours/day).

Measurement of physical activity in leisure time

Subjects were asked "How often do you engage in the following activities in your leisure time?" with the following possible answers: (i) walking slowly; (ii) brisk walking; (iii) moderate-intensity activity such as playing golf or gardening; and (iv) vigorous-intensity activity such as jogging or playing tennis. They were then asked the frequency [(a) <1 time/month; (b) 1–3 times/month; (c) 1–2 times/week; (d) 3–4 times/week; (e) almost every day], and duration [(a) <30 minutes; (b) 30–<59 minutes; (c) 1–<2 hours; (d) 2–<3 hours; (e) 3–<4 hours; (f) ≥4 hours].

The present study defined "brisk walking", "moderate intensity of activity", and "vigorous intensity or stronger intensity of activity" as MVPA in leisure time in line with the current recommendation for physical activity (23). Average time of MVPA in leisure time was determined by multiplying frequency and duration.

Covariates

Each survey gathered information on medical history and health-related behaviors. Covariates used in this

study were age (continuous), residential area (10 public health areas), body mass index (BMI; <18.5, 18.5–<25, or >25 kg/m^2) (24), current smoking (yes, no), excess alcohol consumption (<60 or ≥60 g ethanol/day) (25), current or history of diabetes (yes, no), current or history of hypertension (yes, no), walking time at work (continuous), strenuous work time (continuous), and MVPA in leisure time (continuous).

Statistical analysis

The number of person-years in the follow-up period was counted from the starting point (ie, date of response to the 10-year follow-up questionnaire) to the date of death, emigration from Japan, or the end of the study period, whichever came first. For subjects who withdrew from the study or were lost to follow-up, the date of withdrawal or the last confirmed date of presence in the study was used as the date of censoring.

Hazard ratios (HR) and 95% confidence intervals (95% CI) were used to characterize the relative risk of all-cause mortality associated with occupational sitting levels. To control for potential confounders, the Cox proportional hazard models were employed. The HR of all-cause mortality were calculated for middle or longer occupational sitting time, adjusting for age and residential area (Model 1). We then calculated the HR adjusted for smoking, drinking, BMI, diabetes history, and hypertension status (Model 2), then further adjusted for occupational and leisure time MVPA (Model 3). For each model, those reporting short sitting time were defined as the reference category.

Finally, occupation-stratified multivariate analyses were performed. Since very few subjects engaged in forestry and fishing, analyses were performed only for agricultural workers, salaried workers, home business, and professional workers.

In testing of the proportional hazards assumption, we scaled Schoenfeld residuals and found no violation of proportionality. Since the distribution of occupation was considerably affected by gender, all analyses were conducted separately by gender. In addition, analyses were further conducted separately by occupational classification, ie, by "primary industry" or "secondary or tertiary industry" because sitting behavior also varied by occupation. To assess the interaction between occupational and sitting time, we employed interaction terms for analyses using overall subjects. To reduce the potential for spurious associations from reverse causation, we repeated the above analyses after excluding cases with early death (those occurring within 3 years of the starting point). In the sensitivity analysis, we repeated the above analyses after excluding "subjects with slight physical limitation, but they could drive vehicles or take public transportation alone" in addition to subjects with more severe limitation; ie, analysis was performed only among subjects with no physical limitation. In addition, to ascertain possible selection bias which may occur through exclusion of subjects who have changed jobs within 5 years, we repeated this analysis including them as another sensitivity analysis.

All statistical analyses were performed using STATA software, version 12 (IBM Corp, Armonk, NY, USA); the level of significance was set at P<0.05.

Results

During 368 120 person-years of follow-up (average follow-up period, 10.1 years) for the 36 516 subjects, 2209 deaths were identified.

Baseline characteristics of study subjects according to gender, occupation, and occupational sitting levels are shown in table 1. The mean age of participants was 58.7 [standard deviation (SD) 6.2] years for men and 59.0 (SD 6.2) years for women. Subjects in secondary or tertiary industry tended to smoke and drink excess alcohol to a greater extent than those in primary industry. On comparing workers in primary industry against those in secondary or tertiary industry, we found no significant difference in characteristics except for leisure time MVPA. MVPA in leisure time was observed more among subjects with longer sitting time in both occupations.

Table 2 presents adjusted models showing associations between occupational sitting levels and all-cause mortality, stratified by gender. Overall, there is no significant association between occupational sitting duration and mortality among both men and women. Whereas, among workers in primary industry, longer duration of occupational sitting was significantly or marginally associated with higher mortality (HR 1.23, 95% CI 1.00–1.51 among men; HR 1.34, 95% CI 0.97–1.82 among women). Among male workers, higher occupational sitting was inversely associated in Model 1 (HR 0.83, 95% CI 0.72–0.96). However, the association did not persist in Models 2 and 3. No apparent associations were found among female workers in secondary or tertiary industry (HR 1.03, 95% CI 0.77–1.39). Significant interaction between occupation and sitting time were observed (P<0.001).

Table 3 presents the results of occupation-stratified analysis. Significant associations were observed among agricultural workers (men: HR 1.26, 95% CI 1.01–1.56, women: HR 1.32, 95% CI 0.95–1.82). No apparent associations were found in results for salaried workers, home business, or professional workers.

After excluding early deaths, additional analyses had no substantial effect on the results. In addition, sensitivity analyses of those with no physical limitation, as well as analyses including those who have changed jobs within five years, did not affect the results.

Table 1. Baseline characteristics of participants. [BMI=body mass index; MVPA=moderate-to-vigorous physical activity; SD=standard deviation.]

	Short (<1h/day)				Middle(1–<3h)				Long(≥3h)			
	N	%	Mean	SD	N	%	Mean	SD	N	%	Mean	SD
Primary industry												
Men												
Number of subjects	1561				1220				1219			
Age (years)			63.4	6.6			63.8	6.6			63.9	6.3
BMI (kg/m^2)			23.5	2.9			23.7	2.9			23.7	2.9
Current smoker		36.6				38.1				37.2		
Excess alcohol drinking [a]		29.0				25.8				25.8		
History of diseases												
Hypertension		22.4				23.5				23.9		
Diabetes		5.5				5.4				6.4		
MVPA in leisure time (minutes/week)			38.3	165.3			40.6	127.1			54.1	170.7
Walking time at work (hour/day)			3.0	2.9			3.2	2.6			3.1	2.8
Strenuous work time (hour/day)			3.8	2.8			3.6	2.5			3.4	2.8
Women												
Number of subjects	3572				3724				8567			
Age (years)			57.8	5.5			57.7	5.5			57.2	5.3
BMI (kg/m^2)			23.6	2.9			23.8	2.9			24.1	2.9
Current smoker		47				46.1				43.8		
Excess alcohol drinking		31				30.3				30.5		
History of diseases												
Hypertension		17				17.9				19.6		
Diabetes		7				7.7				7.9		
MVPA in leisure time (minutes/week)			48.5	127.2			58.6	154.1			70.7	257.2
Walking time at work (hour/day)			3.3	2.9			3.2	2.6			3.2	2.7
Strenuous work time (hour/day)			3.0	2.8			2.8	2.5			2.5	2.6
Secondary or tertiary industry												
Men												
Number of subjects	3693				3844				8755			
Age (years)			57.9	5.6			57.3	5.3			57.4	5.3
BMI (kg/m^2)			23.7	2.9			23.9	2.9			24.1	2.9
Current smoker		47.4				46.1				44.0		
Excess alcohol drinking		31.4				30.1				30.5		
History of diseases												
Hypertension		16.8				17.9				19.6		
Diabetes		6.4				7.5				7.8		
MVPA in leisure time (minutes/week)			59.0	168.9			78.8	180.0			84.1	186.2
Walking time at work (hour/day)			3.0	2.9			2.7	2.5			1.7	2.0
Strenuous work time (hour/day)			3.1	2.9			2.3	2.5			1.1	2.0
Women												
Number of subjects	2618				3338				6115			
Age (years)			57.3	5.3			57.3	5.1			57.0	5.3
BMI (kg/m^2)			23.4	3.2			23.5	3.1			23.5	3.2
Current smoker		7.0				7.6				7.1		
Excess alcohol drinking		3.1				2.2				3.1		
History of diseases												
Hypertension		17.3				17.6				16.8		
Diabetes		2.9				3.1				2.7		
MVPA in leisure time (minutes/week)			61.4	148.3			77.0	166.9			74.4	168.8
Walking time at work (hour/day)			3.8	3.2			3.3	2.8			2.4	2.4
Strenuous work time (hour/day)			1.8	2.5			1.4	2.1			0.9	1.7

[a] Excess alcohol drinking was defined as ≥60 mg/day intake of alcohol.

Discussion

The main finding of this study was that longer occupational sitting was significantly associated with higher mortality among workers in primary industry. Meanwhile, no apparent associations were found among workers in secondary or tertiary industry.

Previous longitudinal studies focusing on mortality and occupational physical activity showed inconsistent results (14–19, 26). However, most of these did not distinguish sedentary behavior from physical inactivity. The distinction between "insufficiently active" and "sedentary behaviors" is important (1). The term "physical inactivity" denotes not reaching recommendations for MVPA, whereas sedentary behaviors are defined as

Table 2. Adjusted hazard ratios (HR) of all-cause mortality by industry, gender and sitting time. [MVPA=moderate-to-vigorous physical activity; 95% CI=95% confidence interval]

	Number of Subjects	Person-years	Number of cases	Model 1 [a]		Model 2 [b]		Model 3 [c]	
				HR	95% CI	HR	95% CI	HR	95% CI
Men									
Overall									
Short (<1 hours)	5133	51499	545	1.00		1.00		1.00	
Middle (1->3 hours)	4944	49284	510	0.98	0.86–1.11	1.00	0.88–1.14	1.00	0.88–1.14
Long (≥3 hours)	9786	97300	786	0.92	0.82–1.03	0.96	0.86–1.09	0.97	0.86–1.09
Primary industry									
Short (<1 hours)	1561	15496	240	1.00		1.00		1.00	
Middle (1->3 hours)	1220	11903	229	1.13	0.92–1.39	1.16	0.94–1.43	1.16	0.94–1.43
Long (≥3 hours)	1219	11825	220	1.19	0.97–1.46	1.23	1.00–1.51	1.23	1.00–1.51
Secondary or tertiary industry									
Short (<1 hours)	3572	36003	305	1.00		1.00		1.00	
Middle (1->3 hours)	3724	37381	281	0.89	0.75–1.05	0.91	0.77–1.07	0.91	0.77–1.08
Long (≥3 hours)	8567	85476	566	0.83	0.72–0.96	0.87	0.75–1.01	0.87	0.75–1.01
Women									
Overall									
Short (<1 hours)	4015	40925	143	1.00		1.00		1.00	
Middle (1->3 hours)	4988	50725	197	1.05	0.83–1.33	1.05	0.84–1.33	1.06	0.84–1.33
Long (≥3 hours)	7650	78387	285	1.15	0.93–1.43	1.15	0.92–1.43	1.15	0.92–1.42
Primary industry									
Short (<1 hours)	1415	14529	77	1.00		1.00		1.00	
Middle (1->3 hours)	1670	17094	99	0.98	0.70–1.37	1.00	0.71–1.40	1.01	0.73–1.42
Long (≥3 hours)	1563	16128	118	1.37	0.99–1.88	1.35	0.98–1.86	1.34	0.97–1.84
Secondary or tertiary industry									
Short (<1 hours)	2600	26397	66	1.00		1.00		1.00	
Middle (1->3 hours)	3318	33631	98	1.11	0.81–1.53	1.10	0.80–1.50	1.09	0.80–1.51
Long (≥3 hours)	6087	62259	167	1.04	0.78–1.39	1.03	0.77–1.39	1.03	0.77–1.39

[a] Multivariables were adjusted for age, sex and public health centres.
[b] Model 1 + smoking, drinking, body mass index, diabetes history, walk time at work, strenuous work time, and MVPA in leisure time.
[c] Model 2 + hypertension.

low-energy-expenditure activities (≤1.5 MET) in a sitting or reclining posture. It has been noted that there is often little association between sedentary behavior and MVPA (27, 28), and that it is possible for an individual to accumulate large amounts of both MVPA and sedentary behavior in the course of a day (3, 29–32). Hence, physically inactive workers in past studies may not actually be sedentary workers because they may spend a long time on light-intensity physical activity such as standing at work.

There has been only one cohort study that examined the relationship between occupational sitting time and all-cause mortality while distinguishing between "insufficiently active" and "prolonged sedentary" behaviors. This study evaluated occupational physical activity among 11 168 British men and women (19), and found a positive association between occupational sitting and mortality among female workers independently of MVPA. Our study produced results consistent with this finding, and reinforced the evidence that longer occupational sitting time might be a health risk, at least among women in primary industry.

Regarding possible mechanisms, it has been shown that sedentary time and light-intensity activity, such as slow walking or standing tasks, are reported to be highly negatively correlated; ie, more time spent on light-intensity activity is associated with less time spent on sedentary behavior (33, 34). Furthermore, sedentary behavior includes unique biological mechanisms, as distinct from too little physical activity. Physiologically, it has been suggested that the loss of local contractile stimulation induced by prolonged sitting behavior leads to both the suppression of skeletal muscle lipoprotein lipase activity (which is necessary for triglyceride uptake and high-density lipoprotein cholesterol production) and reduced glucose uptake through blunted translocation of GLUT-4 glucose transporters to the skeletal muscle cell surface (6). In fact, a cross-sectional study showed that frequent breaking up of sedentary time is associated with beneficial health outcomes (35). This study assessed associations between occupational sitting time and all-cause mortality. To clarify the detailed mechanisms involved, future analyses using proximal measures such as biochemical indicators or disease-specific incidence will be helpful. For example, analyses using CVD incidence would be necessary because some biological mechanisms between CVD and sedentary behaviors have been indicated (4, 33). Such analyses are also important for clarifying why association between occupational sitting and mortality was not found among secondary-tertiary industry workers.

The present study showed a potentially deleterious

Table 3. Adjusted hazard ratios (HR) of all-cause mortality by occupation. Multivariables were adjusted for age, sex and public health centers, smoking, drinking, body mass index, diabetes history, hypertension status, moderate-to-vigorous physical activity (MVPA) in leisure-time and walk time at work and strenuous work time. [95% CI=95% confidence interval]

	Number of subjects	Person-years	Number of cases	HR	95% CI
Men					
Agricultural					
Short (<1 hours)	1440	14 310	180	1.00	
Middle (1->3 hours)	1100	10 814	157	1.14	0.92–1.42
Long (≥3 hours)	1301	10 134	161	1.26	1.01–1.56
Salaried worker					
Short (<1 hours)	1446	14 023	98	1.00	
Middle (1->3 hours)	1625	15 627	89	0.87	0.65–1.17
Long (≥3 hours)	5353	51 490	264	0.87	0.67–1.11
Home business					
Short (<1 hours)	1356	13 079	123	1.00	
Middle (1->3 hours)	1460	14 088	126	0.94	0.73–1.20
Long (≥3 hours)	1956	18 782	183	0.97	0.76–1.22
Women					
Professional					
Short (<1 hours)	559	5652	43	1.00	
Middle (1->3 hours)	527	5263	34	0.92	0.58–1.45
Long (≥3 hours)	1094	10 942	74	0.96	0.63–1.45
Agriculture					
Short (<1 hours)	1397	14 332	64	1.00	
Middle (1->3 hours)	1650	16 906	75	1.00	0.72–1.41
Long (≥3 hours)	1535	15 864	94	1.32	0.95–1.82
Salaried worker					
Short (<1 hours)	1195	11 725	21	1.00	
Middle (1->3 hours)	1331	12 923	34	1.46	0.85–2.53
Long (≥3 hours)	3122	31 010	68	1.32	0.79–2.19
Home business					
Short (<1 hours)	718	7129	22	1.00	
Middle (1->3 hours)	1135	11 261	34	1.01	0.58–1.74
Long (≥3 hours)	1670	16 832	53	1.06	0.63–1.77
Professional					
Short (<1 hours)	331	3347	6	1.00	
Middle (1->3 hours)	489	4930	8	0.95	0.32–2.84
Long (≥3 hours)	710	7258	11	0.80	0.28–2.25

impact of prolonged sitting at work. Unlike sitting in leisure time, sitting in occupational time is more likely to be mandatory. Hence, shortening the time spent sitting at work and preventing sitting-related chronic diseases might be issues relevant to occupational health. Owen et al highlighted the importance of interventions to reduce and break up sedentary behaviors among adults in domestic, workplace, and transportation environments (7). For example, the introduction of non-seated working options in occupational environments would be effective. The present study implies that such intervention might be needed.

As expected, the association between occupational sedentary time and all-cause mortality was observed among those engaging in primary industry. However, the relationship was less distinct among workers in secondary or tertiary industry. Although the specific reasons are unknown, the following are some possible explanations. First, we speculated that confounding by high socioeconomic status might be one reason for this unexpected result. Unfortunately, this study did not contain any appropriate indicators regarding individual socioeconomic status; however, a previous Australian study reported that sedentary workers are better educated and have a higher job class (36). It is possible that sedentary workers in secondary or tertiary industry might have higher educational achievements and income levels, which may be related to a healthy lifestyle or better health outcome. Second, the lifestyle transition after retirement may have influenced the results. Many participants in secondary or tertiary industry retired from their regular jobs during the follow-up period, and past studies showed that retirement may coincide with increased leisure time MVPA or sedentary behavior (37, 38). Although changes in physical activity and sedentary time after retirement are unclear, this may have been a contributory factor. A third possible reason concerns the quality of occupational sitting. Static sitting or standing tasks without adequate rest can lead to physical or mental loads among workers (39). It could be speculated that sedentary work in primary industry tends to be more deleterious in nature, whereby workers have little latitude for changing posture or are mandated to remain static or seated for long periods. By contrast, workers in secondary or tertiary industry may have relatively more freedom to sit or stand at will in their offices. Such differences in the characteristics of occupational sitting between workers in primary industry and those in secondary or tertiary industry may therefore lead to inconsistent results.

Regarding duration of occupational sitting, careful interpretation of results is needed. The present study measures sitting time by self-reported measures, which demonstrate less validity compared with objective measurement (40). In fact, accelerometer-measured sitting time among Japanese workers in secondary or tertiary industry was 327 minutes per day on average (N=102, unpublished data). Taking this observation into consideration, self-reported occupational sitting time in this study would be underestimated. Thus, one must take care in interpreting how long is considered excessive for occupational sitting based on self-reported measures. Future epidemiological studies using objective measurements are therefore needed.

It is true that this study suggests that longer occupational sitting may be a health risk. Whereas, a study among 584 Finnish men showed that prolonged standing work in upright posture is a risk of atherosclerosis progression (41). Taking these contrasting observations into consideration, possible u-shape associations between occupational sitting time and health risks might be speculated. In order to confirm detailed dose–response relationships, future studies using objective measures are needed. In addition, future studies are also needed

to ascertain what aspect of occupational sitting (for example lower energy expenditure, mandatory sitting posture, or break) cause health risks.

Some limitations and strengths of our study should be considered. First, all data were collected using self-reporting measures. In particular, measurements to assess occupational physical activity and sitting time potentially suffer from misclassification. There may be workers who engage in strenuous tasks from a sitting posture. Second, we did not measure sitting time during leisure time. The observed associations may be confounded if leisure sitting time was inversely correlated with occupational sitting time. Third, changes in sedentary behavior over time may also have caused misclassification. As mentioned earlier, changes in sedentary behavior attributable to retirement need to be evaluated. Fourth, an appropriate indicator for the assessment of individual educational background, which is a potential confounder, could not be conducted due to availability of such information for half of the population (Cohort I) only in this study.

The strengths of our study are its prospective design with a large sample size, enabling us to uncover the gender-specific effects of occupational sitting and mortality. The response rate and the rate of loss to follow-up are also acceptable. Few prospective studies have focused on occupational sedentary behavior. Thus, the results of this study have implications regarding the potential occupational hazard of sedentary behavior, and suggest a need for intervention for workers engaged in sedentary occupations.

Concluding remarks

Occupational sitting time increased all-cause mortality among primary industry workers, however similar relationships were not observed for secondary-tertiary workers. Future studies are needed to confirm detailed dose–response relationships by using objective measures. In addition, studies using cause-specific mortality data would be important to clarify physiological underlying mechanism.

Acknowledgements

This study was supported by National Cancer Centre Research and Development Fund (23-A-31[toku] and 26-A-2) (since 2011) and a Grant-in-Aid for Cancer Research from the Ministry of Health, Labor and Welfare of Japan (1989–2010). Shigeru Inoue was supported by the Grant-in-Aid for Scientific Research (B): 25282209 from the Japan Ministry of Education, Culture, Sports, Science and Technology.

Manami Inoue is the beneficiary of a financial contribution from the AXA Research Fund as a chair holder on the AXA Department of Health and Human Security, Graduate School of Medicine, The University of Tokyo. The AXA Research Fund had no role in the design, data collection, analysis, interpretation or manuscript drafting, or in the decision to submit the manuscript for publication.

We thank the following study group members for their considerable effort to establish and manage the JPHC study.

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Health and Medicine, Tokyo; Y. Kawaguchi, Tokyo Medical and Dental University, Tokyo; Y. Takashima and Y. Yoshida, Kyorin University, Tokyo; K. Nakamura and R. Takachi, Niigata University, Niigata; J. Ishihara, Sagami Women's University, Kanagawa; S. Matsushima and S. Natsukawa, Saku General Hospital, Nagano; H. Shimizu, Sakihae Institute, Gifu; H. Sugimura, Hamamatsu University School of Medicine, Shizuoka; S. Tominaga, Aichi Cancer Center, Aichi; N. Hamajima, Nagoya University, Aichi; H. Iso and T. Sobue, Osaka University, Osaka; M. Iida, W. Ajiki, and A. Ioka, Osaka Medical Center for Cancer and Cardiovascular Disease, Osaka; S. Sato, Chiba Prefectural Institute of Public Health, Chiba; E. Maruyama, Kobe University, Hyogo; M. Konishi, K. Okada, and I. Saito, Ehime University, Ehime; N. Yasuda, Kochi University, Kochi; S. Kono, Kyushu University, Fukuoka; S. Akiba, Kagoshima University, Kagoshima; T. Isobe, Keio University; Y. Sato, Tokyo Gakugei University.

Conflict of interest

The authors declare no conflicts of interest, including related directorships, stock holdings, or contracts.

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Received for publication: 15 December 2014