Overtime Work and Prevalence of Diabetes in Japanese Employees: Japan Epidemiology Collaboration on Occupational Health Study

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Abstract

**Objective:** Epidemiologic evidence on long working hour and diabetes has been conflicting. We examined the association between overtime work and prevalence of diabetes among Japanese workers.

**Methods:** The subjects were 40,861 employees (35,170 men and 5,691 women), aged 16 to 83 years, of 4 companies in Japan. Hours of overtime were assessed using self-reported questionnaires. Diabetes was defined as a fasting plasma glucose ≥126 mg/dl (7.0 mmol/l), hemoglobin A1c ≥6.5% (48 mmol/mol), or current use of anti-diabetic drug. Multiple logistic regression analysis was used to calculate odds ratio of diabetes for each category of overtime.

**Results:** After adjustment for age, sex, company, smoking, and BMI, there was a suggestion of U-shaped relationship between overtime work and prevalence of diabetes (P for quadratic trend = 0.07). Compared with those who worked <45 hours of overtime per month, the adjusted odds ratios (95% confidence interval) of diabetes were 0.86 (0.77–0.94), 0.69 (0.53–0.89), and 1.03 (0.72–1.46) for those who worked 45–79, 80–99, and ≥100 hours of overtime per month, respectively. In one company (n = 33,807), where other potential confounders including shift work, job position, type of department, alcohol consumption, sleep duration, leisure time physical activity, and family history of diabetes was additionally adjusted for, similar result was obtained (P for quadratic trend = 0.05).

**Conclusions:** Long hours of overtime work may not be associated with increased prevalence of diabetes among Japanese workers.

Introduction

Working long hours has been paid much attention in relation to cardiovascular risk or karoshi, death due to overwork [1,2], possibly caused by short sleep duration, physical inactivity, and prolonged exposure to psychological stress at work [3,4]. Because such deterioration of lifestyle has been linked to diabetes [5,6,7], working long hours may also increase the risk of diabetes. Given working long hours is still common in many countries including

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Japan [8] and that the prevalence of diabetes has been increasing [9], causing a significant health and economic burden [10,11,12], it is important to uncover whether working long hours increases risk of diabetes.

Several studies have addressed the relation of working hours to the risk of diabetes, but their results are inconsistent. A Japanese study [13] and a US study [14] reported an increased risk of diabetes with increasing working hours. In contrast, other Japanese studies found no association [15] or even decreased risk of diabetes [16] with increasing working hours. Some methodological issues in these studies need to be addressed. One is that no previous study has examined the association with extremely long overtime (for instance, ≥100 hours per month) in relation to diabetes. Another is that no study used hemoglobin A1c (HbA1c), a diagnostic test for diabetes recently adopted by the International Expert Committee [17]. Furthermore, sample size in half of previous studies was not large (n = 1,000 to 2,000) [13,16], which may limit their findings.

Here, we cross-sectionally investigated associations between overtime work and prevalence of diabetes among a Japanese working population using a large-scale multiple companies-based data using fasting glucose and HbA1c criterion. We hypothesized that long working hours would be associated with increased prevalence of diabetes. Nonetheless, preventive measures for overtime work related health problem were introduced by the Japanese government in 2002–2005 [18], after or during the all prevalence of diabetes. Nonetheless, preventive measures for overtime work related health problem were introduced by the Japanese government in 2002–2005 [18], after or during the all previous studies was not large (n = 1,000 to 2,000) [13,16], which may limit their findings.

Methods

Study Procedure

Japan Epidemiology Collaboration on Occupational Health (J-ECOH) Study is an ongoing, large-scale study among workers in Japan. According to standard procedure of the study, researchers obtained several types of worker health data including those of periodic health checkup (2008 and thereafter), cardiovascular event (myocardial infarction and stroke), death from all causes, and long-term sick leave (1 month or longer) from participating companies. Additional researches including case-control study on cardiovascular event and nutritional survey were performed in selected companies.

In Japan, employees are obliged to undergo general health examination at least once a year under the health and safety law. Of the 11 participating companies of the J-ECOH Study, 9 provided data on periodic health checkup and a method used by the Japan Diabetes Society, thus we converted it to NGSP equivalent value (%) using the formula: HbA1c (%) = 0.25% [20]. and who received health checkup in non-fasting condition (n = 4,592). Some participants met more than one of the exclusion criteria. Finally, 40,861 participants (35,170 men and 5,691 women) remained for analysis.

General Health Examination

Body height and body weight were measured according to a standard protocol in each company. BMI was calculated as weight in kilograms divided by squared height in meters. History of disease and health-related lifestyle were ascertained using a questionnaire, the content of which differs considerably among participating companies. Biochemical measurements included plasma glucose and HbA1c. HbA1c was measured according to a method used by the Japan Diabetes Society, thus we converted it to the National Glycohemoglobin Standardization Program (NGSP) equivalent value (%) using the formula: HbA1c (%) = 1.02 × HbA1c [Japan Diabetes Society] (%) + 0.25% [20].

Overtime Work Hours

In two companies, employees self-reported overtime work hours at health checkup (<45, 45 to <60, 60 to <80, 80 to <100, or ≥100 hours per month in the last 2 to 3 months; <45, 45 to <80, 80 to <100, or ≥100 hours per month, respectively). In another company, employees self-reported average total working hours per day at the timing of health checkup and monthly overtime were calculated using the following formula: (daily hours worked - 8 h) ×20 days. In the remaining company, employees were asked to self-report their overtime work hours in the last month with 11 response options (from “0 to 10” to “>100 hours” per month) at annual survey, not health checkup, in September. We classified these data on overtime work hours into 4 categories using cutoff point of 45, 80, and 100 hours per month for statistical analysis. In one company, 41–50 hours and 71–80 hours of overtime was categorized into 45–79 hours, and >100 hours into ≥100 hours for statistical analysis.
Diagnosis of Diabetes

Diabetes was diagnosed according to the American Diabetes Association criteria [21] as a fasting plasma glucose level of $\geq 126$ mg/dl ($\geq 7.0$ mmol/L), HbA1c of $\geq 6.5\%$ ($\geq 48$ mmol/mol), or the current use of anti-diabetic drug.

Other Variables

Smoking status (never, past, or current) and, if current smoker, number of cigarettes smoked per day were asked at the time of health check-up.

Detailed information on job, lifestyle, and family history of disease was available in one of these companies and used for adjustment as a sensitivity analysis. The information on shift work, job position, type of department, alcohol consumption, sleep duration, physical activity, and family history of diabetes was assessed using a questionnaire at the time of health check-up. Shift work was categorized as shift worker (rotating or night shift) or non-shift worker. Job position was categorized as high position (department chief, department director, or more) or low position (others). We classified 12 departments into two categories; one was termed “field work” for 4 departments and the rest was termed “non-field work” for 8 departments. Averaged daily ethanol consumption from alcohol beverage was calculated as drinking frequency multiplied by ethanol consumption per drinking day. Average sleep duration were assessed with 4 options ($<5$ hours, $5-<6$ hours, $6-<7$ hours, or $\geq 7$ hours). Total weekly minutes of leisure time physical activity were calculated as frequency of physical activity or sports activity multiplied by duration of the activity.

Statistical Analysis

The difference of age, sex, smoking, and BMI between those who were included in the present analysis and those who were excluded was tested by using t-test for continuous variables and $\chi^2$ test for categorical variables. Means (standard error) and percentages across overtime category were presented for continuous and categorical variables with adjustment for age and sex, respectively. Trend association was assessed using linear regression analysis for continuous variable and using logistic regression for categorical variables by assigning 23, 62, 90, and 100 to categories of categorical variables with adjustment for age and sex. Subjects with long overtime were younger and more likely to be male, non-smokers, and physically inactive in leisure time, slept shorter hours, and had family history of diabetes compared with those with short overtime. As regard work related variables, subjects who worked long overtime tended to be a non-shift worker, in a high job position, and in non-field work-related department than those who worked short overtime.

Table 2 shows the associations between overtime work and prevalence of diabetes. In the age-, sex-, and company-adjusted model, there was a U-shaped manner (P for quadratic trend = 0.038). The adjusted odds ratios (95% confidence intervals) were 1.00 (reference), 0.84 (0.76, 0.93), 0.67 (0.52, 0.87), and 1.03 (0.74, 1.45) for those who worked $<15$, 15 to $<30$, 30 to $<100$, and $\geq 100$ hours of overtime, respectively. After further adjustment for smoking and BMI, the U-shaped relationship remained but became marginally significant (P for quadratic trend = 0.07). In one company (n = 33,007), additional adjustment for shift work, job position, type of department, family history of diabetes, alcohol use, sleep duration, and leisure physical activity did not appreciably alter the associations in model 4 (P for quadratic trend = 0.05). The corresponding odds ratios were 1.03 (0.74, 1.45) for those who worked $<15$, 45 to $<80$, 80 to $<100$, and $\geq 100$ hours of overtime, respectively. After an exclusion of 1,609 subjects who were under treatment for diabetes, results were not materially changed (data not shown).

Table 3 shows odds ratio of diabetes across overtime work by risk factors for diabetes. There was no significant effect modification by age, sex, overweight, shift work, type of department, smoking status, alcohol consumption, sleep duration, and physical activity (all P for interaction $>0.05$).

Discussion

In the present study among Japanese workers, overtime work was associated with diabetes in a U-shaped manner, with the lowest odds ratio of diabetes being observed in persons with 80 to 99 hours of overtime per month. This study not only provides evidence on overtime and diabetes using a large dataset but also extends knowledge to extremely long overtime (100 hours or more per month).

We found a decreasing trend of diabetes prevalence with increasing hours of overtime up to 100 hours per month. This finding is in line with that in a prospective study of Japanese [16], showing a decreased risk of diabetes with increasing working hours (from $<8$ hours to $\geq 11$ hours per day, which approximately correspond to overtime working from none to $\geq 60$ hours per month).
Alternatively, the present finding might be explained by risk for patients in the advanced stage of disease including diabetes. In physicians recommend employers to shorten working hours only overtime. In the participating companies, however, occupational increased prevalence of diabetes among employees with short diseases [18]. Such preventive measures may have lead to the working hours and restriction of working hours of employees with long health guidance by occupational physician for workers with long working hours has recently been introduced [18], including associated with long overtime due to the following reasons. In may not explain the present finding of a low diabetes prevalence in the discordant results.

Differences in the cutoff of overtime work hours may have resulted have contributed to the inconsistent findings. In addition, the government employee [15], mostly blue collar [13], nurse [14], there is no plausible explanation for the mixed results among the countries with long working hours [8], and this allows us to examine the association with extremely long overtime work. Our data did not support a view that extremely long overtime is required by law [18] and might have lead to the null finding; some other factors may contribute to the low diabetes prevalence associated with overtime. A recent Japanese study reported that daily total physical activity level, a protective factor for diabetes [23], was increased with increasing daily overtime working hours [16], suggesting some benefit of increased occupational physical activity on glucose metabolism.

In the present study, overtime working ≥100 hours per month was not associated with either increased or decreased odds of prevalent diabetes. To our knowledge, no previous study has examined the association with such long overtime. Nonetheless, our finding is in line with a study in the US [14], showing no increase in diabetes risk among those who worked ≥61 hours per week (≥84 hours of overtime per month; relative risk, 1.1). We have no clear explanation for the lack of increase in the prevalent diabetes among employees who not only worked extremely long hours but also had unfavorable lifestyles (short sleep hours and physical inactivity on leisure). As mentioned above, health guidance by a doctor for employees with long overtime working is required by law [18] and might have lead to the null finding; however, sensitivity analysis did not appreciably change the result. Our data did not support a view that extremely long overtime deteriorates glucose metabolism.

The strengths of our study include a large-scale data, and diagnosis of diabetes with a combination of fasting plasma glucose, HbA1c, and self-reported medication. Previous studies diagnosed diabetes by self-report [14], screening glycosuria followed by oral glucose tolerance test [13], or fasting glucose [15,16]. Japan is among the countries with long working hours [8], and this allows us to examine the association with extremely long overtime work (100 hours per month or more). The cutoff for the longest overtime work category in the present study was much longer than

### Table 1. Subject characteristics according to overtime work hours.

| Characteristic                | Overtime work (hours per month) | P for trend* |
|------------------------------|---------------------------------|-------------|
| No. of subjects              | <45                             | 45–79       | 80–99 | ≥100 |   |
| Male sex, %                  | 81.5                            | 97.6        | 98.2  | 98.6 | <0.001 |
| Age, year,                  | 46.4 (0.1)                      | 42.8 (0.1)  | 42.5 (0.3) | 42.8 (0.4) | <0.001 |
| Body-mass index, kg/m²       | 23.5 (0.02)                     | 23.4 (0.03) | 23.6 (0.09) | 23.6 (0.14) | 0.74 |
| Body-mass index ≥25 kg/m², % | 28.0                            | 26.8        | 28.0   | 27.1  | 0.1 |
| Current smoker, %           | 40.2                            | 37.2        | 31.4   | 32.7 | <0.001 |
| Alcohol use (≥23 g of ethanol/day), % | 23.6 | 25.1 | 22.7 | 20.1 | 0.38 |
| Sleeping <6 hours per day, % | 45.5                            | 63.1        | 80.5   | 86.3 | <0.001 |
| Leisure time physical activity, % | 15.2 | 11.9 | 8.1 | 6.5 | <0.001 |
| Family history of diabetes, % | 16.0                            | 16.6        | 17.9   | 17.5 | 0.025 |
| Shift worker, %             | 18.0                            | 13.5        | 8.3    | 10.1  | <0.001 |
| Field-work department, %    | 47.8                            | 42.4        | 31.0   | 30.3 | <0.001 |
| High job position, %         | 10.0                            | 22.2        | 34.8   | 36.3 | <0.001 |

Data are adjusted for age and sex, and presented as mean ± standard error unless otherwise specified. *P for trend was obtained from linear regression for continuous variables, or from logistic regression for categorical variables, by assigning 23, 62, 90, and 100 to categories of overtime work.

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month, respectively). Another Japanese study observed no association in diabetes risk between employees working <9 hours and ≥9 hours per day (approximately monthly overtime work < 20 hours and ≥20 hours, respectively) [15]. By contrast, another Japanese study found increased risk of diabetes among men who worked overtime >50 hours per month than those who worked less than 25 hours of overtime [13]. A study in the US [14] reported an increased risk of diabetes among those who worked 41 to 60 hours per week (approximately 4 to 80 hours of overtime per month); and no increase in the risk among those with overtime working ≥84 hours per month than those with no overtime work (working 21 to 40 hours per week). In addition, a recent meta-analysis of the cohort studies found that long working hours were not associated with the increased risk of diabetes [22]. Although there is no plausible explanation for the mixed results among studies, characteristics of subjects (white collar [16], local government employee [15], mostly blue collar [13], nurse [14], and mixture of white and blue collar in the present study) might have contributed to the inconsistent findings. In addition, the differences in the cutoff of overtime work hours may have resulted in the discordant results.

Reversal causality is a concern for cross-sectional studies, but it may not explain the present finding of a low diabetes prevalence associated with long overtime due to the following reasons. In Japan, occupational health system to prevent diseases related to long working hours has recently been introduced [18], including health guidance by occupational physician for workers with long working hours and restriction of working hours of employees with diseases [18]. Such preventive measures may have lead to the increased prevalence of diabetes among employees with short overtime. In the participating companies, however, occupational physicians recommend employers to shorten working hours only for patients in the advanced stage of disease including diabetes. In addition, we confirmed that an exclusion of subjects under medication for diabetes did not appreciably change the result. Alternatively, the present finding might be explained by risk factors for diabetes. Of risk factors we measured, short sleep duration and leisure time physical inactivity were associated with long working hours, and BMI was not. Although smoking rate was decreased with increasing working hours in the present study, adjustment for smoking did not seemingly change the results. Some other factors may contribute to the low diabetes prevalence associated with overtime. A recent Japanese study reported that daily total physical activity level, a protective factor for diabetes [23], was increased with increasing daily overtime working hours [16], suggesting some benefit of increased occupational physical activity on glucose metabolism.

In the present study, overtime working ≥100 hours per month was not associated with either increased or decreased odds of prevalent diabetes. To our knowledge, no previous study has examined the association with such long overtime. Nonetheless, our finding is in line with a study in the US [14], showing no increase in diabetes risk among those who worked ≥61 hours per week (≥84 hours of overtime per month; relative risk, 1.1). We have no clear explanation for the lack of increase in the prevalent diabetes among employees who not only worked extremely long hours but also had unfavorable lifestyles (short sleep hours and physical inactivity on leisure). As mentioned above, health guidance by a doctor for employees with long overtime working is required by law [18] and might have lead to the null finding; however, sensitivity analysis did not appreciably change the result. Our data did not support a view that extremely long overtime deteriorates glucose metabolism.

The strengths of our study include a large-scale data, and diagnosis of diabetes with a combination of fasting plasma glucose, HbA1c, and self-reported medication. Previous studies diagnosed diabetes by self-report [14], screening glycosuria followed by oral glucose tolerance test [13], or fasting glucose [15,16]. Japan is among the countries with long working hours [8], and this allows us to examine the association with extremely long overtime work (100 hours per month or more). The cutoff for the longest overtime work category in the present study was much longer than
those in previous studies, varying from 20 hours to 84 hours per month [13,14,15,16]. Nevertheless, this study has several limitations. First, we cannot infer causal relationships from results of a cross-sectional study. Second, because overtime work was self-reported by using different response options across companies, we chose overtime of 45 hours per month as the reference. In two companies where detailed data on working hours or overtime was available, however, an analysis using other definitions of the reference (working 8 hours per day, which corresponds to no overtime, and 0 to 10 hours of overtime per month) showed similar results, at least up to 80 hours of overtime per month. Third, overtime in the past 1 to 3 months, depending on companies, was assessed only at one time point. Thus, the relationship between long-term exposure to overtime work and diabetes remains elusive.

Table 2. Odds ratio (OR) and 95% confidence interval of diabetes* according to overtime work hours.

| Overtime work (hours per month) | <45 | 45–79 | 80–99 | ≥100 | P for quadratic trend† |
|---------------------------------|-----|-------|-------|------|------------------------|
| 4 companies                     |     |       |       |      |                        |
| No. of subjects                 | 29,308 | 9,648 | 1,369 | 536  |                        |
| No. of cases (%)                | 2418 (8.3) | 583 (6.0) | 64 (4.7) | 38 (7.1) |                        |
| Model 1†                        |     |       |       |      |                        |
| Multivariable-adjusted OR       | 1.00 | 0.84  | 0.67  | 1.03 | 0.038                  |
| (95% confidence interval)       | (Ref) | (0.76, 0.93) | (0.52, 0.87) | (0.74, 1.45) |                        |
| Model 2‡                        |     |       |       |      |                        |
| Multivariable-adjusted OR       | 1.00 | 0.85  | 0.69  | 1.05 | 0.037                  |
| (95% confidence interval)       | (Ref) | (0.77, 0.94) | (0.53, 0.89) | (0.75, 1.48) |                        |
| Model 3§                        |     |       |       |      |                        |
| Multivariable-adjusted OR       | 1.00 | 0.86  | 0.69  | 1.03 | 0.07                   |
| (95% confidence interval)       | (Ref) | (0.77, 0.95) | (0.53, 0.89) | (0.72, 1.46) |                        |
| 1 company                       |     |       |       |      |                        |
| No. of subjects                 | 23,094 | 9,116 | 1,136 | 461  |                        |
| No. of cases (%)                | 1,927 (8.3) | 554 (6.1) | 51 (4.5) | 36 (7.8) |                        |
| Model 1†                        |     |       |       |      |                        |
| Multivariable-adjusted OR       | 1.00 | 0.85  | 0.66  | 1.16 | 0.011                  |
| (95% confidence interval)       | (Ref) | (0.77, 0.94) | (0.49, 0.87) | (0.82, 1.64) |                        |
| Model 2**                       |     |       |       |      |                        |
| Multivariable-adjusted OR       | 1.00 | 0.89  | 0.70  | 1.17 | 0.045                  |
| (95% confidence interval)       | (Ref) | (0.80, 1.00) | (0.52, 0.94) | (0.81, 1.70) |                        |
| Model 3§                        |     |       |       |      |                        |
| Multivariable-adjusted OR       | 1.00 | 0.87  | 0.66  | 1.11 | 0.05                   |
| (95% confidence interval)       | (Ref) | (0.78, 0.97) | (0.49, 0.90) | (0.76, 1.61) |                        |
| Model 4‡                        |     |       |       |      |                        |
| Multivariable-adjusted OR       | 1.00 | 0.88  | 0.67  | 1.12 | 0.05                   |
| (95% confidence interval)       | (Ref) | (0.79, 0.98) | (0.49, 0.90) | (0.77, 1.63) |                        |

Abbreviations: OR, odds ratio; Ref, reference.
*Defined as fasting glucose ≥126 mg/dL (7.0 mmol/l), HbA1c ≥6.5% (48 mmol/mol), or current use of anti-diabetic drug.
†P for quadratic trend obtained from multiple logistic regression analysis by assigning 23, 62, 90, and 100 to categories of overtime work.
‡Model 1 adjusted for age (continuous), sex, and company in 4 companies (n = 40,861).
§Model 2 adjusted for factors in model 1 and smoking status (never, past, or current) in 4 companies (n = 40,861).
∥Model 3 adjusted for factors in model 2 and body mass index (kg/m², continuous) in 4 companies (n = 40,861).
★Model 1 adjusted for age (continuous) and sex in 1 company (n = 33,807).
**Model 2 adjusted for factors in model 1 plus smoking status (never, past, or current), body mass index (kg/m², continuous), alcohol use (non-drinker, drinker consuming >0 to <23 g, 23 to <46 g, or ≥46 g of ethanol per day), family history of diabetes (yes or no), shift work (yes or no), department (field work or non-field work), and job position (high or low) in 1 company (n = 33,807).
||Model 3 adjusted for factors in model 2 and sleep duration (<6 hours, 6 to <7 hours, or ≥7 hours per day) in 1 company (n = 33,807).
{Model 4 adjusted for factors in model 3 and leisure time physical activity (<150 min or ≥150 min per week) in 1 company (n = 33,807).
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### Table 3. Odds ratio with 95% confidence interval of diabetes according to overtime work hours stratified by participant characteristics.

| Overtime work (hours per month) | No. of subjects | <45 | 45–79 | 80–99 | ≥100 | *P* for quadratic trend |
|---------------------------------|-----------------|-----|-------|-------|------|-------------------------|
| **4 companies**                 |                 |     |       |       |      |                         |
| Age                             |                 |     |       |       |      |                         |
| <40 years                       | 11835           | 1.00 (Ref) | 0.88 (0.66, 1.17) | 0.76 (0.40, 1.44) | 0.95 (0.37, 2.44) | 0.69 |
| ≥40 years                       | 29026           | 1.00 (Ref) | 0.85 (0.76, 0.95) | 0.67 (0.50, 0.89) | 1.03 (0.70, 1.49) | 0.07 |
| **Sex**                         |                 |     |       |       |      |                         |
| Men                             | 35170           | 1.00 (Ref) | 0.86 (0.77, 0.95) | 0.70 (0.54, 0.91) | 1.00 (0.70, 1.43) | 0.09 |
| Women                           | 5616‡           | 1.00 (Ref) | 1.04 (0.47, 2.30) | - | 5.21 (0.58, 47.24) | - |
| **Smoking status**              |                 |     |       |       |      |                         |
| Non-smoker                      | 24399           | 1.00 (Ref) | 0.78 (0.68, 0.90) | 0.71 (0.51, 1.00) | 0.96 (0.60, 1.55) | 0.11 |
| Current smoker                  | 16462           | 1.00 (Ref) | 0.94 (0.81, 1.09) | 0.64 (0.42, 0.97) | 1.10 (0.66, 1.84) | 0.33 |
| **BMI (kg/m²)**                 |                 |     |       |       |      |                         |
| <25                             | 29437           | 1.00 (Ref) | 0.84 (0.73, 0.97) | 0.77 (0.53, 1.12) | 1.03 (0.62, 1.73) | 0.19 |
| ≥25                             | 11424           | 1.00 (Ref) | 0.90 (0.78, 1.04) | 0.65 (0.45, 0.94) | 1.08 (0.67, 1.74) | 0.22 |
| **1 company**                   |                 |     |       |       |      |                         |
| Shift work                      |                 |     |       |       |      |                         |
| Non-shift worker                | 27718           | 1.00 (Ref) | 0.86 (0.76, 0.97) | 0.59 (0.42, 0.83) | 1.16 (0.77, 1.73) | 0.026 |
| Shift worker                    | 6089            | 1.00 (Ref) | 0.97 (0.75, 1.26) | 1.32 (0.65, 2.67) | 0.91 (0.32, 2.57) | 0.86 |
| **Type of department**          |                 |     |       |       |      |                         |
| Field work                      | 15464           | 1.00 (Ref) | 0.91 (0.78, 1.06) | 0.68 (0.42, 1.12) | 1.02 (0.55, 1.92) | 0.45 |
| Non-field work                  | 18343           | 1.00 (Ref) | 0.83 (0.71, 0.97) | 0.65 (0.44, 0.95) | 1.13 (0.71, 1.80) | 0.05 |
| **Alcohol use**                 |                 |     |       |       |      |                         |
| <23 g of ethanol/day            | 24674           | 1.00 (Ref) | 0.93 (0.82, 1.06) | 0.62 (0.43, 0.88) | 1.24 (0.82, 1.88) | 0.07 |
| ≥23 g of ethanol/day            | 9133            | 1.00 (Ref) | 0.73 (0.60, 0.90) | 0.79 (0.46, 1.37) | 0.73 (0.30, 1.77) | 0.61 |
| **Sleep duration**              |                 |     |       |       |      |                         |
| <6 hours                        | 17592           | 1.00 (Ref) | 0.87 (0.75, 1.00) | 0.57 (0.39, 0.81) | 1.12 (0.74, 1.69) | 0.049 |
| ≥6 hours                        | 16215           | 1.00 (Ref) | 0.88 (0.74, 1.04) | 1.16 (0.66, 2.01) | 1.12 (0.42, 2.99) | 0.56 |
| **Physical activity**           |                 |     |       |       |      |                         |
| <150 min per week               | 28963           | 1.00 (Ref) | 0.89 (0.79, 1.00) | 0.72 (0.53, 0.98) | 1.16 (0.79, 1.70) | 0.06 |
| ≥150 min per week               | 4844            | 1.00 (Ref) | 0.80 (0.60, 1.07) | 0.13 (0.02, 0.94) | 0.51 (0.06, 3.96) | 0.95 |

Abbreviations: BMI, body mass index; Ref, reference.

*P* for trend obtained from multiple logistic regression analysis by assigning 23, 62, 90, and 100 to categories of overtime work.

Adjusted for age (continuous), sex, company, smoking status (never, past, or current), and BMI (kg/m², continuous) in 4 companies (n = 41,081).

Adjusted for age (continuous), sex, company, smoking status (never, past, or current), BMI (kg/m², continuous), alcohol use (non-drinker, drinker consuming >0 to <23 g, 23 to <46 g, or ≥46 g of ethanol per day), sleep duration (<6 hours, 6 to <7 hours, or ≥7 hours per day), physical activity (<150 min or ≥150 min per week), family history of diabetes (yes or no), shift work (yes or no), department (field work or non-field work), and job position (high or low) in 1 company (n = 33,307).

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confounders including dietary factors, socioeconomic status, and work stress may have influenced the overtime work hours - diabetes association.

In conclusion, this cross-sectional analysis of large-scale data from Japanese workers showed a U-shaped association of overtime work with prevalent diabetes, with no increase in diabetes even among those who worked 100 hours or more of overtime per month, suggesting that overtime work may not be associated with impaired glucose metabolism. The present finding requires confirmation in longitudinal studies.

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References

1. Spurgeon A, Harrington JM, Cooper CL (1997) Health and safety problems associated with long working hours: a review of the current position. Occup Environ Med 54: 367–375.
2. van der Hulst M (2003) Long workhours and health. Scand J Work Environ Health 29: 171–188.
3. Virtanen M, Heikila K, Jokela M, Ferrie JE, Batty GD, et al. (2012) Long working hours and coronary heart disease: a systematic review and meta-analysis. Am J Epidemiol 176: 586–596.
4. Nagai M, Hoshide S, Kario K (2010) Sleep duration as a risk factor for cardiovascular disease: a review of the recent literature. Curr Cardiol Rev 6: 54–61.
5. Cappuccio FP, D’Elia L, Strazzullo P, Miller MA (2010) Quantity and quality of sleep and risk of prevalent, and incident type 2 diabetes: a systematic review and meta-analysis. Diabetes Care 33: 414–420.
6. Weber MB, Oza-Frank R, Staines LR, Ali MK, Narayan KM (2012) Type 2 diabetes in Asian: prevalence, risk factors, and effectiveness of behavioral intervention at individual and population levels. Amnu Rev Nutr 32: 417–439.
7. Nyberg ST, Fransson EI, Heikkila K, Alfredsson L, Casini A, et al. (2013) Job strain and cardiovascular disease risk factors: meta-analysis of individual-participant data from 47,800 men and women. PLoS One 8: e67323.
8. Lee S, McCann D, Messenger J (2007) Working Time Around the World. London: Routledge.
9. Shaw JE, Sicree RA, Zimmet PZ (2010) Global estimates of the prevalence of diabetes for 2010 and 2030. Diabetes Res Clin Prat 87: 4–14.
10. Emerging Risk Factors Collaboration, Sarwar N, Gao P, Seshasai SR, Nohria N, et al. (2010) Diabetes mellitus, fasting blood glucose concentration, and risk of vascular disease: a collaborative meta-analysis of 102 prospective studies. Lancet 375: 2151–2162.
11. Zhang P, Zhang X, Brown J, Vitsinen D, Sicree R, et al. (2010) Global healthcare expenditure on diabetes for 2010 and 2030. Diabetes Res Clin Prat 87: 298–301.
12. Jiang Y, Ben Q, Shen H, Lu W, Zhang Y, et al. (2011) Diabetes mellitus and incidence and mortality of colorectal cancer: a systematic review and meta-analysis of cohort studies. Eur J Epidemiol 26: 865–876.