

# Effects of long work hours and poor sleep characteristics on workplace injury among full-time male employees of small- and medium-scale businesses

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**SUMMARY** The aim of this study was to investigate the effects of long work hours and poor sleep characteristics on workplace injury. A total of 1891 male employees, aged 18–79 years (mean 45 years), in 296 small- and medium-scale businesses in a suburb of Tokyo were surveyed by means of a self-administered questionnaire during August–December 2002. Work hours and sleep characteristics, including daily sleep hours, subjective sleep sufficiency, sleep quality and easiness to wake up in the morning, were evaluated. Information on workplace injury in the past 1-year period was self-reported. The risk of workplace injury associated with work hours and poor sleep was estimated using multivariate logistic regression with odds ratio (ORs) and 95% confidence intervals as measures of associations. Compared with those working 6–8 h day<sup>-1</sup> with good sleep characteristics, positive interactive effects for workplace injury were found between long work hours (>8–10 h day<sup>-1</sup> or >10 h day<sup>-1</sup>) and short sleep duration (<6 h) [adjusted OR (aOR), 1.27–1.54], subjective insufficient sleep (aOR, 1.94–1.99), sleep poorly at night (aOR, 2.23–2.49) and difficulty waking up in the morning (aOR, 1.56–1.59). Long work hours (aOR, 1.31–1.48), subjective insufficient sleep (aOR, 1.49) and sleeping poorly at night (aOR, 1.72) were also independently associated with workplace injury. This study suggests that long work hours coupled with poor sleep characteristics are synergistically associated with increased risk of workplace injury. Greater attention should be paid to manage/treat poor sleep and reduce excessive work hours to improve safety at the workplace.

**KEYWORDS** overtime, safety, sleep, small- and medium-scale business, work hours, workplace injury

## INTRODUCTION

According to estimates by the International Labor Organization in 2005, the number of workplace accidents in the world is increasing, especially in Asia and Latin America. There are 270 million occupational accidents each year, causing 350 000 workplace injury deaths throughout the world (Hamalainen *et al.*, 2006).

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Several epidemiological studies have demonstrated that long work hours is a critical risk factor for workplace injury (Dembe *et al.*, 2005; Dong, 2005; Folkard and Tucker, 2003; Grosch *et al.*, 2006; Vegso *et al.*, 2007). For example, a nationally representative sample of 10 793 working adults in USA demonstrated that working overtime schedules was associated with a 61% higher injury hazard rate compared with jobs without overtime. Working 12 h day<sup>-1</sup> or more was associated with a 37% increased hazard rate, and working 60 h week<sup>-1</sup> or more was associated with a 23% increased hazard rate (Dembe *et al.*, 2005). A study by Folkard and Tucker (2003) showed that the risk of workplace injury increases in an exponential fashion with time on shift, such

that in the 12th hour risk of injury was more than double that during the first 8 h.

In contrast, Allen *et al.* (2007) reported that long work hours had no significant association with acute injury in employees of a heavy manufacturing company ( $n = 2746$ ; Allen *et al.*, 2007). Similarly, a study of fatal occupational accidents in a national sample of 47 860 individuals in Sweden reported that overtime ( $> 50$  h week<sup>-1</sup>) had a 22% decreased risk of accident death at work compared with individuals working  $\leq 50$  h week<sup>-1</sup> (Akerstedt *et al.*, 2002). Inconsistent findings may partially be explained as follows. It is possible that employees who had already suffered from workplace injury or had pre-existing health conditions may have worked lesser hours to reduce their burden, which can cause selection bias leading toward underestimation of the association (Caruso, 2006). More importantly, long work hours often results in a short or disturbed sleep (Basner *et al.*, 2007; Nakashima *et al.*, in press; Virtanen *et al.*, 2009), and it is not well established whether workplace injury is the direct result of excessive work hours or poor sleep, or if they exert a synergistic effect. A number of studies have shown that sleep disturbances and short sleep are associated with increased risk of workplace injuries and accidents (Akerstedt *et al.*, 2002; Balter and Uhlenhuth, 1992; Chau *et al.*, 2004; Gabel and Gerberich, 2002; Nakata *et al.*, 2005; Salminen *et al.*, 2010). A prospective study of Finnish public sector employees ( $n = 48\,598$ ) revealed that the risk of workplace injury was 1.38 times higher for men with experiences of disturbed sleep than for those without sleep disturbances (Salminen *et al.*, 2010). Balter and Uhlenhuth also reported a 4.5 times higher accident rate in individuals with chronic insomnia as compared with those without insomnia (Balter and Uhlenhuth, 1992). These findings consistently suggest that poor sleep is closely related to workplace accidents and injuries. Thus, it seems important to examine the interactive effects of work hours and sleep on workplace injury, which has not been systematically investigated to date.

The current study was therefore designed to examine the effects of work hours and sleep characteristics on workplace injury among a large number of small- and medium-scale businesses (SMBs) comprised of various industry sectors and occupations. Our purpose was to clarify the following three research questions.

- 1 Are long work hours independently related to workplace injury?
- 2 Are poor sleep characteristics independently related to workplace injury?
- 3 Are long work hours and poor sleep characteristics together related to workplace injury?

## MATERIALS AND METHODS

### Study population

The study design was cross-sectional, and data were collected using a self-rated questionnaire between August and Decem-

ber 2002. The study sample consisted of full-time employees of SMBs with 1–158 workers in the city of Yashio, Saitama, and in the Ohta ward of Tokyo. Yashio has the highest percentage of manufacturing plants in Saitama prefecture. The ward of Ohta, which is a so-called 'industrial area', is unique for its number of SMBs. We randomly selected 20% of businesses from both areas weighted according across industry sectors. As a result, 329 businesses from Yashio and 61 from the Ohta ward were included. An occupational health nurse/physician contacted a representative of the company to request participation in the study. Among these businesses, 248 in Yashio and 52 in Ohta agreed to participate. Questionnaires were distributed during visits to each business, and were given to 2591 employees in Yashio and 1102 employees in Ohta ( $n = 3693$ ). Responses were obtained from 2884 employees (2022 men and 862 women) from 296 businesses (response rate 78.1%). Among these, those who had missing responses for sex, age, work hours, sleep variables and workplace injury were eliminated from the analyses ( $n = 198$ ). Also excluded were those who reported working  $< 6$  or  $> 20$  h day<sup>-1</sup> ( $n = 94$ ), or were  $< 18$  years old ( $n = 2$ ). In addition, female employees were excluded because of a small sample size and low injury rate ( $n = 699$ ). Because there were  $< 5\%$  missing responses for the rest of the covariates, missing value analysis was performed (van Ginkel and van der Ark, 2005). The 'expectation-maximization method' of imputing missing values was utilized. Data on a total of 1891 male participants were used in the final analyses. The study was approved by the Medical Ethical Committee of The University of Tokyo.

### Measurements

#### Work hours

Work hours were assessed by an open-ended question: 'How many hours do you usually work in a typical working day?'

#### Sleep characteristics

The following four questions about daily sleep characteristics during the previous 1-year period were included in the questionnaire.

- 1 On average, how much sleep at night do you usually get? ( $< 5$  h; 5 to  $< 6$  h; 6 to  $< 7$  h; 7 to  $< 8$  h; 8 to  $< 9$  h; 9+ h)
- 2 Do you think your daily sleep is sufficient? (very insufficient; somewhat insufficient; fairly sufficient; very sufficient)
- 3 Do you usually sleep well at night? (very well; fairly well; not so well; very poorly)
- 4 Do you feel difficulty waking up in the morning? (not at all; rarely; not very; a little; somewhat; considerably)

Our previous study confirmed a strong convergent and discriminant validity as well as a high level of test-retest stability over 1 year for these questions (Nakata *et al.*, 2008).

### Workplace injury

A 'yes or no' question to assess workplace injury was: 'Have you ever been injured during your work, including minor scratches and cuts in the previous 1-year period?' (Nakata *et al.*, 2006).

### Covariates

Covariates considered included sociodemographic and socioeconomic factors, health behaviors, biological factors and occupational factors (Table 1). Information on height and weight was obtained to assess body mass index, calculated as weight (kg) divided by height (m) squared, and divided into quintiles. Participants were asked if they were treated for any of the following diseases: hypertension, hyperlipidemia, diabetes mellitus, major depression, menopausal disorder, or other disorders. If the participants reported 'other disorders', they were asked to specify the condition. Participants reported various disorders, as listed in Table 1. Among these disorders, we selected eight major diseases (hypertension, hyperlipidemia, diabetes mellitus, menopausal disorders, major depression, cardiovascular disease, stomach/duodenal ulcer and cancer) with a relatively high prevalence as independent covariates, and combined the rest of the disorders as a covariate 'other disorders'. Job control and quantitative workload were evaluated by the Japanese version of the Generic Job Stress Questionnaire, which is a well-established means of measurement (Hurrell and McLaney, 1988; Nakata *et al.*, 2007). Job control measures how much the worker feels that tasks, workplace setting and decisions at work are controllable, and is assessed based on 16 items, while quantitative workload estimates how much work must be done on a daily basis and is based on four items. Internal consistency (Cronbach's  $\alpha$ ) for these scales was 0.96 and 0.88, respectively.

### Statistical analyses

The relationship between work hours and workplace injury, sleep characteristics and covariates was analysed by the chi-squared test. The risk of workplace injury by work hours and sleep characteristics was estimated by univariate and multivariate logistic regression with odds ratios (ORs) and 95% confidence intervals (CIs) as measures of association. The multivariate model adjusted for all potential confounders as listed in Table 1, except quantitative workload because of a strong intercorrelation with work hours. Combined effects of work hours and sleep characteristics were also examined by a similar analytic method. They were divided into four sets of six groups as follows: three groups of work hours (6 to <8 h day<sup>-1</sup>, >8–10 h day<sup>-1</sup> or >10 h day<sup>-1</sup>) × two groups of sleep hours (<6 h or 6+ h) or × two groups of subjective sleep sufficiency (very sufficient/sufficient or insufficient/very insufficient) or × two groups of sleep quality (very well/fairly well or not so well/very poorly) or × two groups of easiness to wake up in the morning (not at all/rarely/not very or a little/somewhat/considerably). The significance level for all statistical analyses

was  $P < 0.05$  (two-tailed test). Data were analysed using IBM SPSS version 17.0 software (SPSS, Chicago, IL, USA).

## RESULTS

Descriptive statistics for participants stratified by work hours are shown in Table 1. Roughly 37% of men worked 6–8 h day<sup>-1</sup>, while 46% and 17% worked >8–10 h day<sup>-1</sup> and >10 h day<sup>-1</sup>, respectively. The mean age was 45.1 years (SD = 13.3), and over 43% of participants were at least 50 years old. About 70% of participants had a high school or lower educational level. Participants rated their household financial situation 'just getting by (48%)' or 'difficult/very difficult (45%)'. The prevalence of smoking was as high as 59%, and only 29% were lifetime non-smokers. Hypertension, hyperlipidemia and diabetes mellitus were the three most prevalent disorders among this population. Overall, 48% of participants indicated that they work in production/manufacturing jobs and 44% in the metalworking sector. About 60% of participants were working in small businesses with <31 employees in total. Work hours were strongly correlated with quantitative workload but not with job control.

The relationship of work hours with workplace injury and sleep variables is shown in Table 2. Work hours did not show significant associations with workplace injury and sleep well at night, but short sleep hours, insufficient sleep and difficulty waking up in the morning were significantly associated with work hours.

Associations of work hours and sleep variables with workplace injury are shown in Table 3. Participants working >10 h day<sup>-1</sup> and >8–10 h day<sup>-1</sup> had significantly higher odds of workplace injury than those working 6–8 h day<sup>-1</sup> (reference category) by multivariate analyses. On the other hand, participants sleeping <5 h day<sup>-1</sup> and 6 to <7 h day<sup>-1</sup> had higher odds of workplace injury compared with those sleeping 7 to <8 h day<sup>-1</sup> (reference category); no significant difference was observed in participants sleeping 5 to <6 h day<sup>-1</sup>, 8 to <9 h day<sup>-1</sup> or 9+ h day<sup>-1</sup>. Subjective sleep sufficiency and sleep poorly at night were both strongly associated with workplace injury, while difficulty waking up in the morning was not associated with workplace injury by multivariate analyses.

The combined effects of work hours and sleep variables on workplace injury are shown in Table 4. As compared with a reference group that had a 6–8 h day<sup>-1</sup> work hours and good sleep characteristics, the odds of workplace injury were higher among participants with either long work hours or poor sleep characteristics, but those who had the longest work hours coupled with poor sleep characteristics yielded the highest risk of workplace injury, suggesting a synergistic effect of work hours and sleep on workplace injury.

## DISCUSSION

The focus of the present study was to clarify the independent association of work hours and sleep characteristics and its

**Table 1** Characteristics of the study participants by work hours ( $n = 1891$ )

| Characteristics                                     | Work hour categories ( $h\ day^{-1}$ ) |            |            |            | P*      |
|---|--|------------|------------|------------|---------|
|   | Total                                  | 6–8        | > 8–10     | > 10       |         |
|   | n (%)                                  | n (%)      | n (%)      | n (%)      |         |
| Number of participants                              | 1891 (100.0)                           | 690 (36.5) | 876 (46.3) | 325 (17.2) |         |
| Sociodemographic and socioeconomic factors          |  |            |            |            |         |
| Age group, years                                    |  |            |            |            | < 0.001 |
| 18–29   | 275 (14.5)                             | 91 (13.2)  | 133 (15.2) | 51 (15.7)  |         |
| 30–39   | 463 (24.5)                             | 135 (19.6) | 215 (24.5) | 113 (34.8) |         |
| 40–49   | 331 (17.5)                             | 115 (16.7) | 159 (18.2) | 57 (17.5)  |         |
| 50–59   | 534 (28.2)                             | 198 (28.7) | 251 (28.7) | 85 (26.2)  |         |
| 60+   | 288 (15.2)                             | 151 (21.9) | 118 (13.5) | 19 (5.8)   |         |
| Marital status                                      |  |            |            |            | 0.379   |
| Married   | 1306 (69.1)                            | 475 (68.8) | 608 (69.4) | 223 (68.6) |         |
| Single  | 496 (26.2)                             | 176 (25.5) | 236 (26.9) | 84 (25.8)  |         |
| Separated/divorced/widowed                          | 89 (4.7)                               | 39 (5.7)   | 32 (3.7)   | 18 (5.5)   |         |
| Highest education                                   |  |            |            |            | < 0.001 |
| Junior high school                                  | 407 (21.5)                             | 183 (26.5) | 191 (21.8) | 33 (10.2)  |         |
| High school   | 881 (46.6)                             | 331 (48.0) | 402 (45.9) | 148 (45.5) |         |
| Vocational/junior college                           | 235 (12.4)                             | 82 (11.9)  | 102 (11.6) | 51 (15.7)  |         |
| College/graduate school                             | 368 (19.5)                             | 94 (13.6)  | 181 (20.7) | 93 (28.6)  |         |
| Number of children in the household                 |  |            |            |            | 0.043   |
| 0   | 968 (51.2)                             | 379 (54.9) | 429 (49.0) | 160 (49.2) |         |
| 1   | 542 (28.7)                             | 198 (28.7) | 255 (29.1) | 89 (27.4)  |         |
| 2   | 282 (14.9)                             | 78 (11.3)  | 146 (16.7) | 58 (17.8)  |         |
| 3+  | 99 (5.2)                               | 35 (5.1)   | 46 (5.3)   | 18 (5.5)   |         |
| Household financial situation                       |  |            |            |            | 0.968   |
| Very comfortable/comfortable                        | 130 (6.9)                              | 45 (6.5)   | 60 (6.8)   | 25 (7.7)   |         |
| Just getting by                                     | 915 (48.4)                             | 338 (49.0) | 422 (48.2) | 155 (47.7) |         |
| Finding it difficult/very difficult                 | 846 (44.7)                             | 307 (44.5) | 394 (45.0) | 145 (44.6) |         |
| Health indicators                                   |  |            |            |            |         |
| Smoking   |  |            |            |            | 0.004   |
| Lifetime non-smoker                                 | 555 (29.3)                             | 222 (32.2) | 241 (27.5) | 92 (28.3)  |         |
| Former smoker                                       | 223 (11.8)                             | 90 (13.0)  | 111 (12.7) | 22 (6.8)   |         |
| Current smoker                                      | 1113 (58.9)                            | 378 (54.8) | 524 (59.8) | 211 (64.9) |         |
| Alcohol consumption ( $g\ ethanol\ day^{-1}$ )      |  |            |            |            | 0.410   |
| Non-drinker (0.0)                                   | 450 (23.8)                             | 183 (26.5) | 196 (22.4) | 71 (21.8)  |         |
| 0.01–4.9  | 246 (13.0)                             | 79 (11.4)  | 117 (13.4) | 50 (15.4)  |         |
| 5.0–14.9  | 427 (22.6)                             | 151 (21.9) | 200 (22.8) | 76 (23.4)  |         |
| 15.0–24.9   | 373 (19.7)                             | 127 (18.4) | 184 (21.0) | 62 (19.1)  |         |
| 25.0 and over                                       | 395 (20.9)                             | 150 (21.7) | 179 (20.4) | 66 (20.3)  |         |
| Caffeine intake (cups of coffee or tea $day^{-1}$ ) |  |            |            |            | < 0.001 |
| Almost none   | 184 (9.7)                              | 76 (11.0)  | 78 (8.9)   | 30 (9.2)   |         |
| 1 cup   | 328 (17.3)                             | 135 (19.6) | 148 (16.9) | 45 (13.8)  |         |
| 2 cups  | 570 (30.1)                             | 207 (30.0) | 287 (32.8) | 76 (23.4)  |         |
| 3–5 cups  | 678 (35.9)                             | 233 (33.8) | 301 (34.4) | 144 (44.3) |         |
| 6 cups or more                                      | 131 (6.9)                              | 39 (5.7)   | 62 (7.1)   | 30 (9.2)   |         |
| Body mass index (in quintiles)                      |  |            |            |            | 0.972   |
| 1st quintile (< 20.1)                               | 312 (16.5)                             | 108 (15.7) | 144 (16.4) | 60 (18.5)  |         |
| 2nd quintile (20.1 to < 21.8)                       | 336 (17.8)                             | 123 (17.8) | 156 (17.8) | 57 (17.5)  |         |
| 3rd quintile (21.8 to < 23.2)                       | 403 (21.3)                             | 150 (21.7) | 185 (21.1) | 68 (20.9)  |         |
| 4th quintile (23.2 to < 25.2)                       | 424 (22.4)                             | 150 (21.7) | 204 (23.3) | 70 (21.5)  |         |
| 5th quintile (25.2 or higher)                       | 416 (22.0)                             | 159 (23.0) | 187 (21.3) | 70 (21.5)  |         |
| Physical disorder(s)                                |  |            |            |            |         |
| Hypertension  |  |            |            |            | 0.008   |
| Present   | 259 (13.7)                             | 116 (16.8) | 109 (12.4) | 34 (10.5)  |         |
| Absent  | 1632 (86.3)                            | 574 (83.2) | 767 (87.6) | 291 (89.5) |         |
| Hyperlipidemia                                      |  |            |            |            | 0.617   |
| Present   | 80 (4.2)                               | 31 (4.5)   | 33 (3.8)   | 16 (4.9)   |         |
| Absent  | 1811 (95.8)                            | 659 (95.5) | 843 (96.2) | 309 (95.1) |         |
| Diabetes mellitus                                   |  |            |            |            | 0.445   |
| Present   | 85 (4.5)                               | 36 (5.2)   | 34 (3.9)   | 15 (4.6)   |         |
| Absent  | 1806 (95.5)                            | 654 (94.8) | 842 (96.1) | 310 (95.4) |         |

| Characteristics   | Work hour categories ( $h\ day^{-1}$ ) |            |            |             | P*     |
|---|--|------------|------------|-------------|--------|
|   | Total                                  | 6–8        | > 8–10     | > 10        |        |
|   | n (%)                                  | n (%)      | n (%)      | n (%)       |        |
| Menopausal disorders                                      |  |            |            |             | 0.359  |
| Present   | 7 (0.4)                                | 4 (0.6)    | 3 (0.3)    | 0 (0.0)     |        |
| Absent  | 1884 (99.6)                            | 686 (99.4) | 873 (99.7) | 325 (100.0) |        |
| Major depression  |  |            |            |             | 0.322  |
| Present   | 10 (0.5)                               | 2 (0.3)    | 7 (0.8)    | 1 (0.3)     |        |
| Absent  | 1881 (99.5)                            | 688 (99.7) | 869 (99.2) | 324 (99.7)  |        |
| Cardiovascular disease                                    |  |            |            |             | 0.153  |
| Present   | 8 (0.4)                                | 5 (0.6)    | 1 (0.1)    | 2 (0.6)     |        |
| Absent  | 1883 (99.6)                            | 685 (99.3) | 875 (99.9) | 323 (99.4)  |        |
| Stomach/duodenal ulcer                                    |  |            |            |             | 0.003  |
| Present   | 23 (1.2)                               | 5 (0.7)    | 8 (0.9)    | 10 (3.1)    |        |
| Absent  | 1868 (98.8)                            | 685 (99.3) | 868 (99.1) | 315 (96.9)  |        |
| Cancer  |  |            |            |             | 0.847  |
| Present   | 7 (0.4)                                | 2 (0.3)    | 4 (0.5)    | 1 (0.3)     |        |
| Absent  | 1884 (99.6)                            | 688 (99.7) | 872 (99.5) | 324 (99.7)  |        |
| Other disorders†  |  |            |            |             | 0.802  |
| Present   | 69 (3.6)                               | 35 (5.1)   | 20 (4.5)   | 14 (4.3)    |        |
| Absent  | 1803 (95.3)                            | 655 (94.9) | 837 (95.5) | 311 (95.7)  |        |
| Occupational factors                                      |  |            |            |             |        |
| Main job type   |  |            |            |             | <0.001 |
| Managerial/clerical                                       | 347 (18.4)                             | 99 (14.3)  | 167 (19.1) | 81 (24.9)   |        |
| Sales/service   | 175 (9.3)                              | 32 (4.6)   | 83 (9.5)   | 60 (18.5)   |        |
| Technical   | 80 (4.2)                               | 25 (3.6)   | 35 (4.0)   | 20 (6.2)    |        |
| Production/manufacturing                                  | 915 (48.4)                             | 395 (57.2) | 414 (47.3) | 106 (32.6)  |        |
| Other   | 374 (19.8)                             | 139 (20.1) | 177 (20.2) | 58 (17.8)   |        |
| Industry sector   |  |            |            |             | <0.001 |
| Ceramic/clay/stone  | 26 (1.4)                               | 17 (2.5)   | 9 (1.0)    | 0 (0.0)     |        |
| Textile   | 26 (1.4)                               | 9 (1.3)    | 15 (1.7)   | 2 (0.6)     |        |
| Papermaking   | 74 (3.9)                               | 24 (3.5)   | 32 (3.7)   | 18 (5.5)    |        |
| Printing  | 29 (1.5)                               | 10 (1.4)   | 12 (1.4)   | 7 (2.2)     |        |
| Chemical  | 235 (12.4)                             | 83 (12.0)  | 125 (14.3) | 27 (8.3)    |        |
| Leather   | 10 (0.5)                               | 4 (0.6)    | 5 (0.6)    | 1 (0.3)     |        |
| Metalworking  | 839 (44.4)                             | 362 (52.5) | 385 (43.9) | 92 (28.3)   |        |
| Food  | 95 (5.0)                               | 21 (3.0)   | 40 (4.6)   | 34 (10.5)   |        |
| Machinery   | 307 (16.2)                             | 96 (13.9)  | 140 (16.0) | 71 (21.8)   |        |
| Other   | 250 (13.2)                             | 64 (9.3)   | 113 (12.9) | 73 (22.5)   |        |
| Work schedule   |  |            |            |             | 0.690  |
| Non-shift daytime   | 1734 (91.7)                            | 637 (92.3) | 802 (91.6) | 295 (90.8)  |        |
| Shift work (rotating shift/<br>night shift/evening shift) | 157 (8.3)                              | 53 (7.7)   | 74 (8.4)   | 30 (9.2)    |        |
| Size of company by number<br>of employees (in quintiles)  |  |            |            |             | <0.001 |
| 1–8 workers   | 334 (17.7)                             | 159 (23.0) | 144 (16.4) | 31 (9.5)    |        |
| 9–18 workers  | 385 (20.4)                             | 148 (21.4) | 185 (21.1) | 52 (16.0)   |        |
| 19–31 workers   | 407 (21.5)                             | 149 (21.6) | 193 (22.0) | 65 (20.0)   |        |
| 32–61 workers   | 424 (22.4)                             | 121 (17.5) | 211 (24.1) | 92 (28.3)   |        |
| 62+ workers   | 341 (18.0)                             | 113 (16.4) | 143 (16.3) | 85 (26.2)   |        |
| Job control (in tertiles)                                 |  |            |            |             | 0.126  |
| High  | 712 (37.7)                             | 237 (34.3) | 337 (38.5) | 138 (42.5)  |        |
| Medium  | 622 (32.9)                             | 237 (34.3) | 290 (33.1) | 95 (29.2)   |        |
| Low   | 557 (29.5)                             | 216 (31.3) | 249 (28.4) | 92 (28.3)   |        |
| Quantitative workload (in tertiles)                       |  |            |            |             | <0.001 |
| Low   | 652 (34.5)                             | 310 (44.9) | 284 (32.4) | 58 (17.8)   |        |
| Medium  | 624 (33.0)                             | 224 (32.5) | 300 (34.2) | 100 (30.8)  |        |
| High  | 615 (32.5)                             | 156 (22.6) | 292 (33.3) | 167 (51.4)  |        |

\*Chi-squared test or Fischer's exact test (comparison within work hour groups).

†Other disorders include arrhythmia, gout, hyperuricemia, renal disease, liver disease, stroke, gynecological diseases, hyperthyroidism, peptic ulcer, severe allergy, panic disorders, hernia, and rheumatoid arthritis.

**Table 2** Association of work hours with workplace injury and sleep variables ( $n = 1891$ )

| Variables                           | Work hour category ( $h\ day^{-1}$ ) |            |            |            | P*      |
|-------------------------------------|--------------------------------------|------------|------------|------------|---------|
|                                     | Total                                | 6–8        | > 8–10     | > 10       |         |
|                                     | n (%)                                | n (%)      | n (%)      | n (%)      |         |
| Number of participants              | 1891 (100.0)                         | 690 (36.5) | 876 (46.3) | 325 (17.2) |         |
| Workplace injury                    |                                      |            |            |            | 0.210   |
| Yes                                 | 740 (39.1)                           | 252 (36.5) | 355 (40.5) | 133 (40.9) |         |
| No                                  | 1151 (60.9)                          | 438 (63.5) | 521 (59.5) | 192 (59.1) |         |
| Sleep $h\ day^{-1}$                 |                                      |            |            |            | < 0.001 |
| < 5                                 | 175 (9.3)                            | 49 (7.1)   | 64 (7.3)   | 62 (19.1)  |         |
| 5 to < 6                            | 552 (29.2)                           | 155 (22.5) | 262 (29.9) | 135 (41.5) |         |
| 6 to < 7                            | 734 (38.8)                           | 292 (42.3) | 353 (40.3) | 89 (27.4)  |         |
| 7 to < 8                            | 330 (17.5)                           | 139 (20.1) | 159 (18.2) | 32 (9.8)   |         |
| 8 to < 9                            | 85 (4.5)                             | 47 (6.8)   | 32 (3.7)   | 6 (1.8)    |         |
| 9+                                  | 15 (0.8)                             | 8 (1.2)    | 6 (0.7)    | 1 (0.3)    |         |
| Sleep $h\ day^{-1}$                 |                                      |            |            |            | < 0.001 |
| < 6                                 | 727 (38.4)                           | 204 (29.6) | 326 (62.8) | 197 (39.4) |         |
| 6+                                  | 1164 (61.6)                          | 486 (70.4) | 550 (37.2) | 128 (60.6) |         |
| Subjective sleep sufficiency        |                                      |            |            |            | < 0.001 |
| Very sufficient                     | 280 (14.8)                           | 141 (20.4) | 118 (13.5) | 21 (6.5)   |         |
| Sufficient                          | 716 (37.9)                           | 278 (40.3) | 350 (40.0) | 88 (27.1)  |         |
| Insufficient                        | 718 (38.0)                           | 223 (32.3) | 336 (38.4) | 159 (48.9) |         |
| Very insufficient                   | 177 (9.4)                            | 48 (7.0)   | 72 (8.2)   | 57 (17.5)  |         |
| Subjective sleep sufficiency        |                                      |            |            |            | < 0.001 |
| Very sufficient/sufficient          | 996 (52.7)                           | 419 (60.7) | 468 (53.4) | 109 (33.5) |         |
| Insufficient/very insufficient      | 895 (47.3)                           | 271 (39.3) | 408 (46.6) | 216 (66.5) |         |
| Sleep well at night (sleep quality) |                                      |            |            |            | 0.149   |
| Very well                           | 379 (20.0)                           | 146 (21.1) | 175 (20.0) | 58 (17.8)  |         |
| Fairly well                         | 1199 (63.4)                          | 433 (62.8) | 565 (64.5) | 201 (61.8) |         |
| Not so well                         | 275 (14.5)                           | 92 (13.3)  | 122 (13.9) | 61 (18.8)  |         |
| Very poorly                         | 38 (2.0)                             | 19 (2.8)   | 14 (1.6)   | 5 (1.5)    |         |
| Sleep well at night (sleep quality) |                                      |            |            |            | 0.129   |
| Very well/fairly well               | 1578 (83.4)                          | 579 (83.9) | 740 (84.5) | 259 (79.7) |         |
| Not so well/very poorly             | 313 (16.6)                           | 111 (16.1) | 136 (15.5) | 66 (20.3)  |         |
| Difficulty waking up in the morning |                                      |            |            |            | 0.021   |
| Not at all                          | 202 (10.7)                           | 83 (12.0)  | 91 (10.4)  | 28 (8.6)   |         |
| Rarely                              | 373 (19.7)                           | 143 (20.7) | 167 (19.1) | 63 (19.4)  |         |
| Not very                            | 464 (24.5)                           | 185 (26.8) | 213 (24.3) | 66 (20.3)  |         |
| A little                            | 418 (22.1)                           | 141 (20.4) | 205 (23.4) | 72 (22.2)  |         |
| Somewhat                            | 266 (14.1)                           | 84 (12.2)  | 130 (14.8) | 52 (16.0)  |         |
| Considerably                        | 168 (8.9)                            | 54 (7.8)   | 70 (8.0)   | 44 (13.5)  |         |
| Difficulty waking up in the morning |                                      |            |            |            | 0.002   |
| Not at all/rarely/not very/a little | 1039 (54.9)                          | 411 (59.6) | 471 (53.8) | 157 (48.3) |         |
| A little/somewhat/considerably      | 852 (45.1)                           | 279 (40.4) | 405 (46.2) | 168 (51.7) |         |

\*Chi-squared test or Fischer's exact test (comparison within work hour groups).

combined effects on workplace injury in a large number of employees at SMBs in a suburb of Tokyo. The results revealed the following: (i) long work hours ( $> 10\ h\ day^{-1}$  and  $> 8\text{--}10\ h\ day^{-1}$ ) were moderately associated with increased workplace injury; (ii) subjective insufficient sleep and sleep poorly at night were strongly related to workplace injury, while short sleep hours ( $< 6\ h\ day^{-1}$ ) and difficulty waking up in the morning were not clearly associated with injury; and (iii) the combination of long work hours with poor sleep characteristics had synergistic effects on workplace injury, and this effect was most pronounced when poor sleep characteristics were combined with the longest work hours ( $> 10\ h\ day^{-1}$ ). In light of these

findings, it seems important to manage/treat employees who are working excessive hours with poor sleep quality and short sleep to prevent workplace injuries.

As described above, previous reports on the relationship between work hours and workplace injury have not yielded consistent results. This inconsistency may be explained by the fact that almost all previous studies have not considered the mediating role of sleep on the relationship between work hours and workplace injury. In support of this assumption, for example, the Whitehall II cohort study reported that working more than  $55\ h\ week^{-1}$ , compared with working  $35\text{--}40\ h\ week^{-1}$ , was associated with 1.98 times higher odds

| <b>Table 3</b> Univariate and multivariate results for risk of workplace injury associated with work hours and sleep variables |                        |         |                       |         |
|--|------------------------|---------|-----------------------|---------|
| Variables  | Workplace injury       |         |                       |         |
|  | Unadjusted OR (95% CI) | P       | Adjusted* OR (95% CI) | P       |
| Work h day <sup>-1</sup>   |                        |         |                       |         |
| 6–8  | 1.00 (reference)       |         | 1.00 (reference)      |         |
| > 8–10   | 1.18 (0.96, 1.45)      | 0.107   | 1.31 (1.05, 1.65)     | 0.018   |
| > 10   | 1.20 (0.92, 1.58)      | 0.178   | 1.48 (1.08, 2.03)     | 0.015   |
| Sleep h day <sup>-1</sup>  |                        |         |                       |         |
| < 5  | 1.72 (1.18, 2.51)      | 0.004   | 1.50 (0.98, 2.30)     | 0.059   |
| 5 to < 6   | 1.28 (0.96, 1.70)      | 0.095   | 1.15 (0.83, 1.58)     | 0.407   |
| 6 to < 7   | 1.36 (1.04, 1.79)      | 0.027   | 1.29 (0.96, 1.74)     | 0.091   |
| 7 to < 8   | 1.00 (reference)       |         | 1.00 (reference)      |         |
| 8 to < 9   | 1.09 (0.66, 1.80)      | 0.733   | 0.93 (0.55, 1.60)     | 0.802   |
| 9+   | 1.75 (0.62, 4.95)      | 0.292   | 1.43 (0.45, 4.49)     | 0.545   |
| Sleep h day <sup>-1</sup>  |                        |         |                       |         |
| < 6  | 1.14 (0.92, 1.35)      | 0.265   | 1.03 (0.83, 1.28)     | 0.788   |
| 6+   | 1.00 (reference)       |         | 1.00 (reference)      |         |
| Subjective sleep sufficiency   |                        |         |                       |         |
| Very sufficient  | 1.00 (reference)       |         | 1.00 (reference)      |         |
| Sufficient   | 1.05 (0.78, 1.40)      | 0.764   | 1.07 (0.78, 1.46)     | 0.692   |
| Insufficient   | 1.57 (1.18, 2.10)      | 0.002   | 1.50 (1.08, 2.07)     | 0.014   |
| Very insufficient  | 1.94 (1.32, 2.86)      | < 0.001 | 1.88 (1.21, 2.92)     | 0.005   |
| Subjective sleep sufficiency   |                        |         |                       |         |
| Very sufficient/sufficient   | 1.00 (reference)       |         | 1.00 (reference)      |         |
| Insufficient/very insufficient   | 1.59 (1.32, 1.91)      | < 0.001 | 1.49 (1.20, 1.84)     | < 0.001 |
| Sleep well at night (sleep quality)  |                        |         |                       |         |
| Very well  | 1.00 (reference)       |         | 1.00 (reference)      |         |
| Fairly well  | 1.21 (0.95, 1.55)      | 0.119   | 1.14 (0.88, 1.49)     | 0.324   |
| Not so well  | 1.97 (1.43, 2.71)      | < 0.001 | 1.83 (1.29, 2.59)     | 0.001   |
| Very poorly  | 2.45 (1.25, 4.81)      | 0.009   | 2.31 (1.11, 4.81)     | 0.025   |
| Sleep well at night (sleep quality)  |                        |         |                       |         |
| Very well/fairly well  | 1.00 (reference)       |         | 1.00 (reference)      |         |
| Not so well/very poorly  | 1.74 (1.37, 2.23)      | < 0.001 | 1.70 (1.30, 2.22)     | < 0.001 |
| Difficulty waking up in the morning  |                        |         |                       |         |
| Not at all   | 1.00 (reference)       |         | 1.00 (reference)      |         |
| Rarely   | 1.17 (0.81, 1.68)      | 0.398   | 1.09 (0.73, 1.61)     | 0.681   |
| Not very   | 1.11 (0.78, 1.57)      | 0.575   | 0.92 (0.62, 1.34)     | 0.648   |
| A little   | 1.67 (1.17, 2.37)      | 0.004   | 1.20 (0.81, 1.77)     | 0.365   |
| Somewhat   | 1.59 (1.09, 2.33)      | 0.017   | 1.12 (0.73, 1.71)     | 0.612   |
| Considerably   | 1.62 (1.06, 2.48)      | 0.025   | 1.01 (0.62, 1.65)     | 0.965   |
| Difficulty waking up in the morning  |                        |         |                       |         |
| Not at all/rarely/not very   | 1.00 (reference)       |         | 1.00 (reference)      |         |
| A little/somewhat/considerably   | 1.48 (1.23, 1.78)      | < 0.001 | 1.16 (0.93, 1.44)     | 0.190   |

\*Adjusted for age group, educational level, marital status, number of children in the household, household financial situation, smoking, drinking, caffeine intake, body mass index (in quintiles), hypertension (yes/no), hyperlipidemia (yes/no), diabetes mellitus (yes/no), major depression (yes/no), cardiovascular disease (yes/no), menopausal disorders (yes/no), stomach/duodenal ulcer (yes/no), cancer (yes/no), other disorders (yes/no), main job type, industry sector, work schedule, company size (in quintiles), and job control (high/medium/low). CI, confidence interval; OR, odds ratio.

for shortened sleep hours (< 7 h day<sup>-1</sup>) in their cross-sectional assessment, while repeated exposure to long work hours was associated with up to 3.24 times higher odds for shortened sleep (Virtanen *et al.*, 2009). Similarly, in automobile assembly line workers, overtime was significantly associated with severe sleepiness at work, which may directly connect to workplace injuries (Son *et al.*, 2008). These findings together with our results support the notion that excessive work hours and poor sleep characteristics influence each other, resulting in increased risk of workplace injuries and accidents.

The current study has further implications for strategies to reduce injuries at the workplace. As indicated in the results (Table 4), work hours and sleep are interactively related to workplace injury, suggesting that merely reducing work hours or increasing sleep hours may not prevent injuries dramatically. Sleep problems could persist even though work hours are reduced, and sleep quality is known to be affected by factors such as work stress, working conditions and poor health behaviors (Caruso *et al.*, 2006; Gadinger *et al.*, 2009; Nakata *et al.*, 2007, 2008; Son *et al.*, 2008). Thus, to prevent workplace

**Table 4** Combined associations of work hours and sleep variables with workplace injury ( $n = 1891$ )\*

| Combinations   | n (%)      | Unadjusted        |        | Adjusted*         |        |
|--|------------|-------------------|--------|-------------------|--------|
|  |            | OR (95% CI)       | P      | OR (95% CI)       | P      |
| <b>Work hours and sleep hours</b>  |            |                   |        |                   |        |
| Work 6–8 h day <sup>-1</sup> with sleep 6+ h day <sup>-1</sup>                       | 486 (25.7) | 1.00 (reference)  |        | 1.00 (reference)  |        |
| Work 6–8 h day <sup>-1</sup> with sleep <6 h day <sup>-1</sup>                       | 204 (10.8) | 1.08 (0.77, 1.51) | 0.665  | 0.89 (0.61, 1.28) | 0.515  |
| Work >8–10 h day <sup>-1</sup> with sleep 6+ h day <sup>-1</sup>                     | 550 (29.1) | 1.17 (0.91, 1.50) | 0.230  | 1.27 (0.97, 1.67) | 0.084  |
| Work >8–10 h day <sup>-1</sup> with sleep <6 h day <sup>-1</sup>                     | 326 (17.2) | 1.29 (0.97, 1.72) | 0.084  | 1.27 (0.92, 1.75) | 0.153  |
| Work >10 h day <sup>-1</sup> with sleep 6+ h day <sup>-1</sup>                       | 128 (6.8)  | 1.18 (0.79, 1.76) | 0.424  | 1.26 (0.80, 1.98) | 0.312  |
| Work >10 h day <sup>-1</sup> with sleep <6 h day <sup>-1</sup>                       | 197 (10.4) | 1.27 (0.91, 1.18) | 0.170  | 1.54 (1.04, 2.28) | 0.032  |
| <b>Work hours and subjective sleep sufficiency</b>                                   |            |                   |        |                   |        |
| Work 6–8 h day <sup>-1</sup> with sufficient sleep                                   | 419 (22.2) | 1.00 (reference)  |        | 1.00 (reference)  |        |
| Work 6–8 h day <sup>-1</sup> with insufficient sleep                                 | 271 (14.3) | 1.64 (1.20, 2.25) | 0.002  | 1.58 (1.12, 2.23) | 0.010  |
| Work >8–10 h day <sup>-1</sup> with sufficient sleep                                 | 468 (24.7) | 1.14 (0.86, 1.50) | 0.370  | 1.35 (1.00, 1.83) | 0.050  |
| Work >8–10 h day <sup>-1</sup> with insufficient sleep                               | 408 (21.6) | 1.89 (1.43, 2.51) | <0.001 | 1.94 (1.41, 2.68) | <0.001 |
| Work >10 h day <sup>-1</sup> with sufficient sleep                                   | 109 (5.8)  | 1.28 (0.83, 1.99) | 0.266  | 1.59 (0.97, 2.58) | 0.064  |
| Work >10 h day <sup>-1</sup> with insufficient sleep                                 | 216 (11.4) | 1.58 (1.12, 2.22) | <0.001 | 1.99 (1.34, 2.96) | <0.001 |
| <b>Work hours and sleep quality</b>  |            |                   |        |                   |        |
| Work 6–8 h day <sup>-1</sup> and sleep well at night                                 | 579 (30.6) | 1.00 (reference)  |        | 1.00 (reference)  |        |
| Work 6–8 h day <sup>-1</sup> and sleep poorly at night                               | 111 (5.9)  | 1.90 (1.26, 2.87) | 0.002  | 1.76 (1.12, 2.75) | 0.014  |
| Work >8–10 h day <sup>-1</sup> and sleep well at night                               | 140 (39.1) | 1.22 (0.97, 1.54) | 0.084  | 1.35 (1.05, 1.73) | 0.019  |
| Work >8–10 h day <sup>-1</sup> and sleep poorly at night                             | 136 (7.2)  | 2.00 (1.37, 2.91) | <0.001 | 2.19 (1.44, 3.32) | <0.001 |
| Work >10 h day <sup>-1</sup> and sleep well at night                                 | 259 (13.5) | 1.20 (0.89, 1.63) | 0.240  | 1.46 (1.03, 2.06) | 0.035  |
| Work >10 h day <sup>-1</sup> and sleep poorly at night                               | 66 (3.5)   | 2.06 (1.23, 3.44) | 0.006  | 2.57 (1.45, 4.55) | <0.001 |
| <b>Work hours and waking up in the morning</b>                                       |            |                   |        |                   |        |
| Work 6–8 h day <sup>-1</sup> without reporting difficulty waking up in the morning   | 411 (21.7) | 1.00 (reference)  |        | 1.00 (reference)  |        |
| Work 6–8 h day <sup>-1</sup> with reporting difficulty waking up in the morning      | 279 (14.8) | 1.56 (1.14, 2.13) | 0.006  | 1.25 (0.88, 1.76) | 0.211  |
| Work >8–10 h day <sup>-1</sup> without reporting difficulty waking up in the morning | 471 (24.9) | 1.16 (0.88, 1.53) | 0.301  | 1.34 (1.00, 1.82) | 0.054  |
| Work >8–10 h day <sup>-1</sup> with reporting difficulty waking up in the morning    | 405 (21.4) | 1.79 (1.35, 2.38) | <0.001 | 1.59 (1.15, 2.19) | 0.005  |
| Work >10 h day <sup>-1</sup> without reporting difficulty waking up in the morning   | 157 (8.3)  | 1.36 (0.93, 2.00) | 0.110  | 1.74 (1.13, 2.67) | 0.012  |
| Work >10 h day <sup>-1</sup> with reporting difficulty waking up in the morning      | 168 (8.9)  | 1.53 (1.06, 2.21) | 0.024  | 1.56 (1.01, 2.39) | 0.044  |

\*Adjusted for age group, educational level, marital status, number of children in the household, household financial situation, smoking, drinking, caffeine intake, body mass index (in quintiles), hypertension (yes/no), hyperlipidemia (yes/no), major depression (yes/no), diabetes mellitus (yes/no), cardiovascular disease (yes/no), menopausal disorders (yes/no), stomach/duodenal ulcer (yes/no), cancer (yes/no), other disorders (yes/no), main job type, industry sector, work schedule, company size (in quintiles), and job control (high/medium/low). CI, confidence interval; OR, odds ratio.

injuries, comprehensive developmental strategies are needed. One such way is to introduce a short nap (<20 min) in the early afternoon to improve alertness at work, which may provide a safer and healthier workplace (Takahashi *et al.*, 2004). Also, workplaces could provide fatigue risk management training to employees and managers that includes strategies to get sufficient good-quality sleep.

A principal strength of this study is that it explored not only the independent association of work hours and sleep with workplace injury, but also evaluated its combined effect on workplace injury in a fairly large number of full-time employees of SMBs composed of various industry sectors and occupations. In addition, participants working <6 and >20 h day<sup>-1</sup> were excluded to minimize selection bias, leading to underestimation. Furthermore, the analyses have adjusted

for a number of potential confounders known to be associated with both dependent and independent variables. On the other hand, there are a number of limitations. First, the study was cross-sectional in nature; thus, no causal interpretations can be made. Second, work hours, sleep status and workplace injury were assessed by self-report rather than through the use of objective measures, such as recording for work hours, polysomnography or certified injury record (Nakashima *et al.*, in press; Salminen *et al.*, 2010). Such measures are desirable, but it is often difficult to adopt these measures simultaneously in epidemiological studies. In addition, differences in sleep characteristics during weekdays and weekends, commuting time or work during off-days were not taken into account. Third, response bias may have occurred if non-respondents differed from respondents; in particular, those who worked

extremely long hours may have had less time available to respond to the questionnaire. Fourth, failure to investigate the nature, severity and circumstance of injury is a major limitation of this study. In addition, questionnaires that record all injuries, including minor ones, can lead to high injury prevalence as well as a source of response bias. Also, lack of data on lost days, interruption in work or hospitalization due to injury prevents us from learning of the aftereffects of injury. Finally, although we adjusted for a variety of confounding variables, we could not exclude the possibility that unmeasured confounders, such as physical exercise, usage of psychoactive medication and social factors, may explain the present findings.

In conclusion, this study found independent associations of work hours and poor sleep characteristics with workplace injury. More importantly, these two factors showed synergistic influences upon workplace injury when tested simultaneously. Prospective research is warranted to determine the causal mechanisms underlying the present findings.

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## CONFLICT OF INTERESTS

None declared.

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