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Characteristics of long working hours and subsequent psychological and physical responses: JNIOSH cohort study

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ABSTRACT

Objectives This study aimed to examine the prospective association among objectively measured average working hours (AWHs), frequency of long working hours (FLWHs; defined as ≥ 205 working hours/month (≥ 45 hours/week)) for 6 months, and workers' self-reported psychological and physical health.

Methods The study included 15 143 workers from 5 Japanese companies. We collected monthly attendance records over 6 months before distributing a questionnaire survey on psychological/physical stress responses and work-related demographics. We then evaluated the associations of those attendance records with psychological/physical measures using analysis of covariance adjusted for sex, age, employment, job type, working conditions, work site and experience of emergency state due to COVID-19.

Results Irritability, anxiety and depression were significantly greater at ≥ 180 hours (≥ 45 hours/week), and fatigue and lack of vigour were greater at ≥ 205 hours than those of the normal working-hour group (140–180 hours/month [35–45 hours/week]). Psychological indices increased significantly with FLWH, with ≥ 3 times for irritability, depression and fatigue; ≥ 2 times for lack of vigour; and ≥ 1 time for anxiety when compared with no long working hours. No significant associations were observed between AWH or FLWH and physical stress responses.

Conclusions Longer AWH was associated with higher levels of psychological stress responses. The effects of FLWH in the past 6 months varied among the psychological stress responses and did not occur for physical complaints. Under circumstances requiring long hours, workers' mental health should be protected through minimising the frequency of long work hours.

INTRODUCTION

The negative impact of long working hours on worker health is of ongoing topical interest. Several epidemiological studies have examined the relationship between long working hours and physical health disorders, including cerebrovascular and cardiovascular diseases,^{1–4} hypertension,^{5–6} metabolic syndrome,⁷ and alcohol use,⁸ among others.^{9–10} Given the importance of workers to be both mentally and physically healthy to ensure the value of work, a more detailed examination of the relationship between long working hours and mental health is as essential as examining

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Despite numerous studies examining the potential harmful effects of long working hours on workers' psychological health, conclusions remain inconsistent. One study indicated that Asian countries have a higher risk of depression with a work week of ≥ 55 hours. However, few studies have objectively assessed working hours and examined their impact on psychological health.

WHAT THIS STUDY ADDS

⇒ The unique feature of this study is that we obtained objective working-hour data for a 6-month period, calculated average monthly working hours and frequency (intensity) of long working hours, and examined the relationship between working-hour indicators and subjective mental health. Longer average working hours were associated with an increase in both psychological and physical stress responses, whereas more frequent long working hours were associated with impaired psychological health.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Regarding the relationship between working hours and workers' health issues, a single questionnaire is often used to assess working hours. The working hours assessment in this study may reveal unknown effects of long working hours on health and well-being. The current results of psychological stress response according to the frequency of long working hours during a given time period can inform the timing of intervention to protect psychological health as an occupational health practice. Our findings also emphasise the critical benefits of avoiding frequent long working hours.

its relationship with physical health.^{11–13} Similar to physical health, mental health is affected by various factors including social relationships,^{14–15} harassment,¹⁶ employment,^{17–19} demand-control-support,¹⁴ effort-reward imbalance²⁰ and organisational justice.²¹ A major issue in occupational health



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is impaired psychological health associated with long working hours.^{8 22 23}

In occupational epidemiology, the association between long working hours and psychological disorders has long been discussed. Watanabe *et al* considered seven studies and concluded that the effects of overwork on diagnosed (not self-reported) depressive disorders remain inconclusive and may be small.²⁴ Virtanen *et al* examined 10 published and unpublished studies (comprising 189 729 participants) in a meta-analysis and reported a significant association between long working hours (defined as ≥ 55 hours/week) and depressive symptoms. Notably, this association differed between Asian and European countries.²⁵ A meta-analysis from WHO/International Labour Organization (ILO) of 32 studies with 109 906 participants found that the quality of evidence of association between long working hours and incidence of depression was low.⁸ However, working hours in these studies were predominantly determined using a single questionnaire (self-report) or via interviews by experts. Hence, it remains questionable whether these measures adequately reflect working hours. Furthermore, the outcomes of many studies were depression or other mental disorders (illnesses). Conversely, we focused on stress responses as a primary prevention for workers' ill health. This is because temporary prevention (including designing and managing work to minimise harm) is effective for addressing mental disorders and may be the most effective approach to avoid serious situations, including suicide, as well as ensuring workers are healthy physically, mentally and socially to engage in their work.²⁶

Numerous studies have investigated the relationship between long working hours and physical and mental health problems. However, scant attention has been paid to the measurement of working hours as an exposure factor. Except for few studies,^{27 28} most findings on the health risk of long working hours are based on workers' self-reported working hours for just one point of their working life, but in reality, workers may be exposed to various working hours, including peak and off-peak periods. One study used 24-month attendance of 922 workers, and the average annual overtime hours were calculated and compared with the psychological stress response of depression symptoms by dividing the overtime change into five groups: a stable short-time group, decreased group, stable medium overtime group, increased group, and stable long overtime group. Results showed that the decreased group had lower depressive responses than the stable short, stable medium and increased groups. There was no significant difference between the decreased group and the stable long overtime group.²⁷ Another study used 3-month attendance of 377 workers to examine the association between overwork and physical/mental status. The overworked group was defined as workers who have worked more than 45 hours per month of overtime in any month during the preceding 3-month period. The result showed no relationship between overtime work and depression and physical symptoms.²⁸ In our ongoing series of studies, we focused on measuring working hours as an exposure factor. Our analysis revealed the need to identify objective approaches to measure working hours that consider a certain period of time rather than a single point in time.^{29 30} Hence, this exploratory study aimed to examine the association of 6-month average (total) working hours (AWH; objectively measured) and frequency (intensity) or accumulation of long working hours (FLWH) over a 6-month period with workers' subsequent psychological and physical stress reactions.

METHODS

Participants

Workers from five Japanese companies participated in this cohort study by the National Institute of Occupational Safety and Health, Japan.³¹ Although eight companies had agreed to participate in this cohort study, the survey participation start date varies from each company, and five companies had provided the whole data at this analysis. Participants were from real estate, construction, transportation, amusement, and retail industries and worked in management, sales, clerical roles and others. All participants provided written informed consent online after receiving information regarding the study purpose and procedures. Among 34 711 eligible employees, 15 944 agreed to participate (response rate=45.9%, figure 1). Workers with no missing data were included in the analysis (n=15 143).

Measures

AWH over 6 months

We gathered working-hour information from the monthly attendance management system of the personnel department of each company. The workers' attendance data were mainly recorded using an electronic attendance management system. Some of the participant companies requested employees to report their working hours and approved those data as their attendance records after examination by supervisors and/or the human resources department using the workers' computer switch-on/switch-off times. Data on working hours were obtained from different time periods for each company. We collected monthly attendance data from 6 months to 1 month before psychological indicators were assessed. Specifically, we collected attendance data from June to November 2019 for company no. 1, April to September 2020 for company no. 2, April to September 2018 for company no. 3, March to August 2020 for company no. 4 and March to August 2019 for company no. 5. The workers were divided into six groups according to their AWH, based on previous studies and meta-analyses,^{25 26} and to the upper limit of overtime hours in Japan (45 hours overtime per month, equivalent to 205 working hours per month as the prescribed working hours are 160 hours per month),³⁰ as follows: <140 hours/month (equivalent to >35 hours/week), 140–180 hours/month (35–45 hours/week), 180–205 hours/month (45–51.25 hours/week), 205–220 hours/month (51.25–55 hours/week) and ≥ 220 hours/month (≥ 55 hours/week) groups.

FLWH within 6 months

In this study, we defined long working hours as ≥ 45 hours/month overtime (160 hours of predetermined working hours plus 45 hours of maximum overtime) according to Japan's overtime limit. Frequency (ie, zero, once, twice...) was counted from the same period as that for AWH.

Psychological and physical stress responses

Psychological and physical health was examined using a self-reported questionnaire through web survey in the month following attendance data collection. Work-related psychological and physical stress responses were assessed using the corresponding subscales of the Brief Job Stress Questionnaire (BJSQ).³² The BJSQ assesses participants about their state in the last month using four-point Likert response options (from 1: almost never to 4: almost always). In the BJSQ, psychological stress responses comprise subscales of vigour (the opposite of lack of vigour), irritability, anxiety, depression and fatigue and physical stress responses comprise questions on various somatic

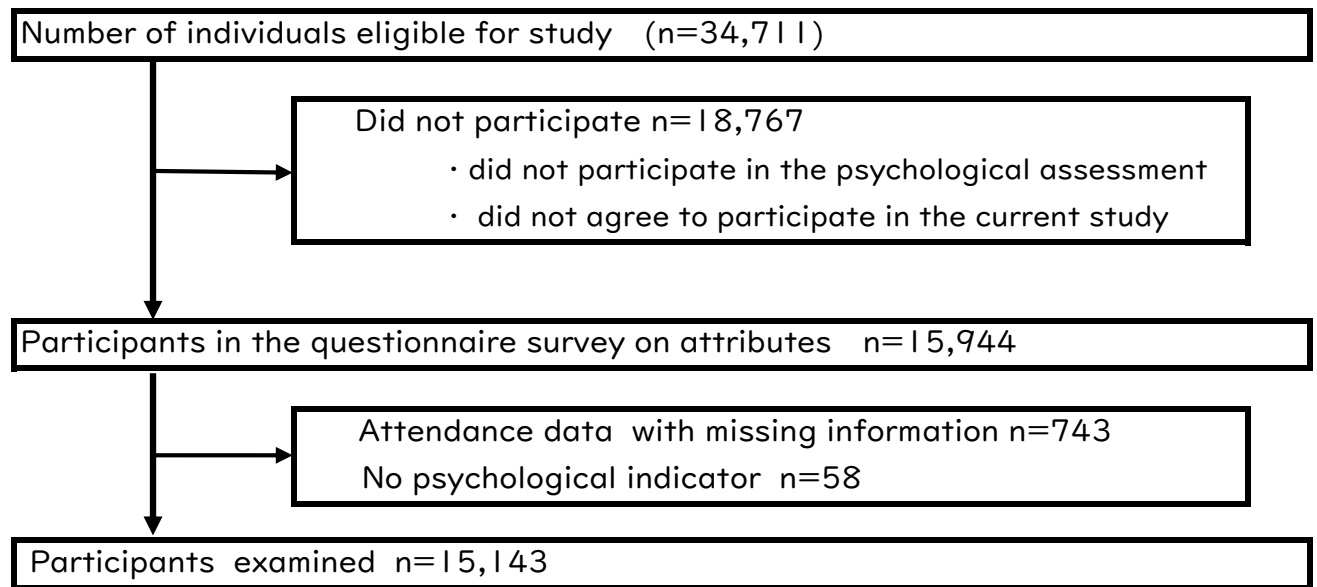


Figure 1 Number of individuals who provided data and were included in the analysis.

symptoms, including headaches, stiff neck and lower back pain. BJSQ is predominantly used for the primary prevention of stress-related mental health problems and is not used for diagnoses. With the exception of vigour, higher scores indicate higher stress responses. Higher scores for vigour means lower stress. Examples of items are presented in online supplemental material 1. Data were provided as mean scores for each subscale.

Covariates

Participants were questioned about employment type, job category, work schedule and work site as covariates using an online questionnaire. Data on participants' age and sex were gathered when psychological indicators were collected. During the working-hour measurement period, some workers experienced changes in the work environment owing to the declaration of an emergency state caused by the COVID-19 pandemic throughout Japan in April 2020. A proportion of workers started telecommuting or continued to work while taking countermeasures against infection. This event was considered to affect workers' psychological and physical stress responses and the presence of that experience was also considered as a covariate.

Statistical analyses

Demographic factors among workers in the AWH and FLWH categories were summed up by attribute. The associations of monthly AWH and FLWH with psychological and physical stress responses were examined using analyses of covariance (ANCOVA). Three models were used for analyses. The crude model had no adjustments. Model 1 was adjusted for sex, age, employment type (regular or non-regular employees, including contract workers, fixed-term employees, temporary staff and part-time workers), job type, work schedule (shift work or non-shift work) and worksite. The same model (model 1) was adjusted for the experience of declaration of a state of emergency caused by COVID-19. The partial eta squared was calculated as the effect size. If there was a significant difference by ANCOVA, the Bonferroni correction was applied for multiple comparisons, and the results related to the reference group (140–180 hours/

month and zero hour groups, respectively) were noted. P values <0.05 indicated statistical significance (two-tailed test). Cases with missing data were excluded from the analysis. All analyses were performed using IBM SPSS Statistics (V.26).

RESULTS

Demographic characteristics of the study participants

The total number of participants was 15 143 (9457 men and 5686 women, see [figure 1](#). [Table 1](#) presents the characteristics of the participants, excluding those with missing outcomes by AWH category. Online supplemental table 1 shows detailed information. The mean ages were 41.9 years (SD=11.9 years) for men and 43.3 years (SD=12.8 years) for women. Overall, 5354 participants experienced COVID-19 emergencies during the assessment period (35.4%). For AWH, 9793 workers (64.7%) were classified into the 140–180 hours/month reference group. [Table 2](#) and online supplemental table 2 present the characteristics of these participants considering FLWH. In total, 12 394 (81.8%) workers had not worked for >205 hours within a 6-month period at any given time. Because the six times FLWH group was very small (n=49), we combined the five and six times groups into one category.

Association between AWH over 6 months and subsequent psychological/physical stress responses

[Table 3](#) presents the final model on the association between AWH of 6 months and subsequent psychological and physical stress responses. The crude model and model 1 are available in online supplemental table 3. In the crude model, significant associations were found between AWH and both psychological/physical stress responses. In models 1 and 2, all psychological stress responses were significantly associated with AWH. In model 2, the results of multiple comparisons revealed that longer AWH was significantly associated with greater irritability, anxiety, fatigue and lack of vigour than that in the reference group (140–180 hours/month). In particular, compared with the 140–180 hours/month (35–45 hours/week) group, the

Table 1 Distribution of attributes by average working hours (AWHs) over the past 6 months

		<140 hour/month (>35 hour/week)	140–180 hour/month (35–45 hour/week)	180–205 hour/month (45–51.25 hour/week)	205–220 hour/month (51.25–55 hour/week)	≥220 hour/month (≥55 hour/week)
		(n=2454)	(n=9793)	(n=2287)	(n=424)	(n=185)
		N (%)	n (%)	n (%)	n (%)	n (%)
Sex	Men	960 (39.1)	6305 (64.4)	1949 (85.2)	379 (89.4)	174 (94.1)
	Women	1494 (60.9)	3488 (35.6)	338 (14.8)	45 (10.6)	11 (5.9)
Age group	≤29 years	407 (16.6)	1840 (18.8)	444 (19.4)	110 (25.9)	41 (22.2)
	30–39 years	601 (24.5)	2431 (24.8)	634 (27.7)	132 (31.1)	53 (28.6)
	40–49 years	548 (22.3)	2364 (24.1)	614 (26.8)	102 (24.1)	44 (23.8)
	50–59 years	457 (18.6)	2115 (21.6)	480 (21.0)	70 (16.5)	45 (24.3)
	≥60 years	441 (18.0)	1043 (10.7)	115 (5.0)	10 (2.4)	2 (1.1)
Shift work	No	2087 (85.0)	9180 (93.7)	2234 (97.7)	414 (97.6)	183 (98.9)
	Yes	367 (15.0)	613 (6.3)	53 (2.3)	10 (2.4)	2 (1.1)
COVID-19	No experience	1629 (66.4)	6714 (68.6)	1308 (57.2)	102 (24.1)	36 (19.5)
	Experience	825 (33.6)	3079 (31.4)	979 (42.8)	322 (75.9)	149 (80.5)

180–205 (45–51.25 hours/week), 205–220 (51.25–55 hours/week) and ≥220 hours/month (≥55 hours/week) groups reported irritability, anxiety and depression while the 205–220 (51.25–55 hours/week) and ≥220 hours/month (≥55 hours/week) groups reported less vigour and greater fatigue. Regarding physical stress responses, AWH was not significantly associated with physical stress responses in models 1 and 2.

Association between FLWH and psychological/physical stress responses

Table 4 presents the association between FLWH and workers' self-reported psychological and physical stress responses in model 2. The crude model and model 1 are available in online supplemental table 4. In the crude model, a significant association was found between FLWH and psychological stress responses. In models 1 and 2, significant associations were noted between FLWH and psychological stress responses. In model 2, compared with the zero group, the more than twice group reported less vigour; all groups reported greater anxiety; and the three, four and five/six times group reported greater irritability, depression and fatigue. No significant relationship was found between FLWH and physical complaints.

DISCUSSION

We examined the association between objectively measured 6-month AWH/FLWH and workers' self-reported psychological/physical health. This study has three main findings. First, AWH was significantly associated with five types of psychological stress responses. The results of multiple comparison showed that compared with the reference group, longer AWH was followed by higher levels of most psychological stress responses. Specifically, irritability, anxiety and depression increased with slightly longer working hours (≥180 hours/month or ≥35 hours/week group) compared with the reference group (140–180 hours/month or 35–45 hours/week), and lack of vigour and fatigue, increased for working hours of ≥205 hours/month (≥0.51.25/week). Second, FLWH was associated with psychological stress responses. Finally, there was no significant association between indicators of AWH/FLWH and physical stress response. The effect size was small as a whole, consistent with previous research.²⁴

Several studies have reported that working ≥55 hours/week (≥220 hours/month) is associated with illnesses, including depressive symptoms and anxiety disorders.^{33 34} Indeed, we observed significant relationships between working-hour

Table 2 Distribution of attributes by frequency of long working hours (≥205 hour/month) within the past 6 months (FLWH)

		Zero (n=12 394)		Once (n=1049)		Twice (n=617)		Three times (n=478)		Four times (n=392)		Five/Six times (n=213)	
		n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)
Sex	Men	7334	(59.2)	907	(86.5)	557	(90.3)	418	(87.4)	361	(92.1)	190	(89.2)
	Women	5060	(40.8)	142	(13.5)	60	(9.7)	60	(12.6)	31	(7.9)	23	(10.8)
Age group	≤29 years	2227	(18.0)	216	(20.6)	146	(23.7)	111	(23.2)	91	(23.2)	51	(23.9)
	30–39 years	3093	(25.0)	275	(26.2)	162	(26.3)	141	(29.5)	113	(28.8)	67	(31.5)
	40–49 years	3028	(24.4)	266	(25.4)	141	(22.9)	99	(20.7)	95	(24.2)	43	(20.2)
	50–59 years	2578	(20.8)	228	(21.7)	130	(21.1)	103	(21.5)	81	(20.7)	47	(22.1)
	≥60 years	1468	(11.8)	64	(6.1)	38	(6.2)	24	(5.0)	12	(3.1)	5	(2.3)
Shift work	No	11 394	(91.9)	1032	(98.4)	606	(98.2)	470	(98.3)	386	(98.5)	210	(98.6)
	Yes	1000	(8.1)	17	(1.6)	11	(1.8)	8	(1.7)	6	(1.5)	3	(1.4)
COVID-19	No experience	8803	(71.0)	488	(46.5)	239	(38.7)	141	(29.5)	61	(15.6)	57	(26.8)
	Experience	3591	(29.0)	561	(53.5)	378	(61.3)	337	(70.5)	331	(84.4)	156	(73.2)

FLWH, frequency of long working hour.

Table 3 Association between average working hours for the past 6 months and stress response scores (model 2)*†

Stress responses	AWH	Model 2*† (final model)			
		Mean (SE)	P value	η^2 ‡	Multiple comparison p value§
Vigour	I. <140 hour/month¶ (<35 hour/week)	2.30 (0.02)	0.000	0.003	0.560
	II. 140–180 hour/month (35–45 hour/week)	2.26 (0.01)			ref
	III. 180–205 hour/month (45–51.25 hour/week)	2.20 (0.02)			0.067
	IV. 205–220 hour/month (51.25–55 hour/week)	2.08 (0.04)			0.000
	V. \geq 220 hour/month (\geq 55 hour/week)	1.97 (0.06)			0.000
Irritability	I. <140 hour/month	1.98 (0.02)	0.000	0.005	0.036
	II. 140–180 hour/month	2.04 (0.01)			ref
	III. 180–205 hour/month	2.12 (0.02)			0.000
	IV. 205–220 hour/month	2.25 (0.04)			0.000
	V. \geq 220 hour/month	2.26 (0.06)			0.001
Anxiety	I. <140 hour/month	1.83 (0.02)	0.000	0.008	0.029
	II. 140–180 hour/month	1.89 (0.01)			ref
	III. 180–205 hour/month	2.01 (0.02)			0.000
	IV. 205–220 hour/month	2.17 (0.04)			0.000
	V. \geq 220 hour/month	2.17 (0.05)			0.000
Depression	I. <140 hour/month	1.77 (0.02)	0.000	0.003	1.000
	II. 140–180 hour/month	1.78 (0.01)			ref
	III. 180–205 hour/month	1.85 (0.02)			0.000
	IV. 205–220 hour/month	1.95 (0.04)			0.000
	V. \geq 220 hour/month	1.96 (0.05)			0.008
Fatigue	I. <140 hour/month	2.04 (0.02)	0.000	0.004	1.000
	II. 140–180 hour/month	2.05 (0.01)			ref
	III. 180–205 hour/month	2.07 (0.02)			1.000
	IV. 205–220 hour/month	2.30 (0.04)			0.000
	V. \geq 220 hour/month	2.33 (0.06)			0.000
Physical complaint	I. <140 hour/month	1.75 (0.01)	0.074	0.001	1.000
	II. 140–180 hour/month	1.75 (0.01)			ref
	III. 180–205 hour/month	1.76 (0.01)			1.000
	IV. 205–220 hour/month	1.83 (0.03)			0.052
	V. \geq 220 hour/month	1.79 (0.04)			1.000

*Crude model and model 1 are shown in online supplemental materials.

†Model 2 was adjusted for sex, age, job type, employment type (regular employee or others), work style (shift work or no shift work), worksite and experience or no experience with COVID-19 emergencies in April 2020.

‡Partial eta squared.

§Bonferroni method.

¶Number of participants in each category is as follows: I: 2,454; II: 9,793; III: 2,287; IV: 424; V: 185.

AWH, average working hour; ref, reference; SE, standard error.

indicators and psychological stress responses at >180 hours/month (\geq 45 hours/week), which was <55 hours/week. A potential reason for this discrepancy is that the outcomes in previous studies were diagnosed diseases, whereas the outcomes in this study were stress responses. As mentioned in the Measures section, the BJSQ focuses on primary prevention of stress-related mental health problems. However, one study reported that the results of the BJSQ may predict long-term sick leave among employees when workers meet high-risk criteria.³⁵ Furthermore, another study showed that workers with psychological and physical stress responses assessed as having ‘high stress’ in the BJSQ have a higher risk of subsequent depression.³⁶ In these two studies, the criterion for evaluating a highly stressed person was based on a high psychological stress response in the total points of psychological/physical stress responses.^{35 36} In contrast, this study examined the relationship of each psychological (lack of vigour, irritability, anxiety, depression and fatigue) and physical stress response with working hours. We confirmed that not all psychological stress responses increased at the same working hours. According to a published report on BJSQ items using the item response theory (IRT), psychological responses, including irritability, anxiety, depression and fatigue, were

highly discriminating, while lack of vigour and physical stress responses were less sensitive.³² In a previous report, the rate of the correspondence curve (irritability, anxiety, depression and fatigue) increased sharply at a certain stress level, indicating a sensitive response. Conversely, the slopes of the response curves for ‘lack of vigour’ and ‘physical stress responses’ were modest, and the corresponding responses were observed in a wide range of ‘stress levels’, highlighting the lack of sensitivity. The slope of the response curve for ‘lack of vigour’ increased gradually at the lowest stress level, followed by a sharp increase in ‘irritability’ and ‘fatigue’ the same number of times, followed by a sharp increase in ‘anxiety’. Moreover, ‘depression’ was rarely reported at low stress levels, whereas the highest stress level was associated with a sharp increase in ‘depression’.³⁰ The IRT results indicate that psychological stress responses may manifest in this order with an increase in stress levels. In contrast, physical stress responses do not show a clear threshold, suggesting that physical stress responses may be underscored by factors other than stress.³²

A preceding cross-sectional study reported that compared with those who worked <60 hours of overtime (equivalent to <220 hours/month), workers who worked 61–80 hours/month

Table 4 Association between frequency of long working hours (FLWH) for the past 6 months and stress response scores (model 2)*†

Stress responses	FLWH	Model 2*† (final model)			
		Mean (SE)	P value	η^2 ‡	Multiple comparison, p value§
Vigour	I.Zero¶	2.27 (0.01)	0.000	0.004	ref
	II. Once	2.20 (0.03)			
	III. Twice	2.16 (0.03)			
	IV. Three times	2.13 (0.04)			
	V.Four times	2.09 (0.04)			
	VI. Five/six times	1.93 (0.06)			
Irritability	I.Zero	2.03 (0.01)	0.000	0.004	ref
	II. Once	2.10 (0.02)			
	III. Twice	2.10 (0.03)			
	IV. Three times	2.17 (0.04)			
	V.Four times	2.20 (0.04)			
	VI. Five/six times	2.31 (0.05)			
Anxiety	I.Zero	1.88 (0.01)	0.000	0.009	ref
	II. Once	1.98 (0.02)			
	III. Twice	2.04 (0.03)			
	IV. Three times	2.11 (0.03)			
	V.Four times	2.17 (0.04)			
	VI. Five/six times	2.18 (0.05)			
Depression	I.Zero	1.78 (0.01)	0.000	0.002	ref
	II. Once	1.82 (0.02)			
	III. Twice	1.85 (0.03)			
	IV. Three times	1.89 (0.03)			
	V.Four times	1.91 (0.04)			
	VI. Five/six times	1.97 (0.05)			
Fatigue	I.Zero	2.04 (0.01)	0.000	0.004	ref
	II. Once	2.06 (0.03)			
	III. Twice	2.09 (0.03)			
	IV. Three times	2.19 (0.04)			
	V.Four times	2.24 (0.04)			
	VI. Five/six times	2.38 (0.06)			
Physical complaint	I.Zero	1.75 (0.01)	0.343	0.000	ref
	II. Once	1.76 (0.02)			
	III. Twice	1.76 (0.02)			
	IV. Three times	1.81 (0.03)			
	V.Four times	1.77 (0.03)			
	VI. Five/six times	1.80 (0.04)			

*Crude model and model 1 are showed in online supplemental materials.

†Model 2 was adjusted for adjusted for sex, age, job type, employment type (regular employee or others), work style (shift work or no shift work), worksite and experience or no experience with COVID-19 emergencies in April 2020.

‡Partial eta squared.

§Bonferroni method.

¶Number of participants in each category is as follows: I: 2,454; II: 9,793; III: 2,287; IV: 424; V: 185.

ref, reference; SE, standard error.

of overtime (equivalent to ≥ 220 working hours/month) exhibited higher vitality and fatigue/anxiety.³⁷ The authors of the study had referred to the classical stress model, and inferred that the mechanism of the simultaneous appearance of high vigour and fatigue/anxiety was a reflection of the so-called ‘runner’s high’ state, which is caused by the activation of hormones during the early to mid-stages of the stress response. However, if we consider this runner’s high in a short time frame, as in the classical stress model,³² the AWH of this duration (over 6 months) may increase both the sense of fatigue and lack of vigour at ≥ 205 hours/month (≥ 51.25 hours/week).

FLWH was associated with psychological stress responses in a different manner. In this regard, psychological stress responses may increase with FLWH in the order of anxiety (once or more), lack of vigour (twice or more) and irritability/depression/fatigue (three times), similar to responses in different AWH groups. For

workers experiencing several months of long working hours within 6 months, other psychological stress responses may be experienced sequentially. These results highlight the importance of examining AWH as well as long working hours over a certain duration. A previous study that followed attendance data for two periods showed that depression may be attenuated when overtime decreased within a year.²⁷ We observed that even one-time FLWH increased anxiety compared with no long working hours. Notably, as the frequency increases to two or three times long working hours, several types of psychological stress responses may increase. The mechanism is unclear, but these results give us an alarm of when to intervene in workplaces where long hours are a common occurrence.

No association between AWH/FLWH and physical stress response was found. There are at least three plausible explanations for the results. First, physical complaints are more likely to

be underscored by pre-existing physical conditions and current state of health.³⁸ Second, there may be a subset of workers who refrained from working long hours because they were in poor physical condition.³⁸ Finally, physical stress responses in the BJSQ are determined by a combination of various types of physical complaints. In the future, it may be necessary to consider each physical complaint separately.

This study had several strengths and limitations. One strength is that the companies provided us with worker attendance data (ie, objectively measured working hours). Another strength is that we examined the association of AWH over 6 months and FLWH with workers' stress responses, for occupational health staff and/or others around the workplace to advise and intervene with workers who work long hours. In addition, we focused on psychological stress responses rather than the onset of mental disorders, which provided useful insights into workers' mental health. Furthermore, we examined multiple aspects of psychological stress responses, including lack of vigour, irritability, anxiety, depression and fatigue. One limitation of this study is that although we used objectively recorded working hours, there is a possibility that working-hour records are not always objectively recorded; however, the Japanese government requires companies to confirm that there are no events that inhibit the proper reporting of working hours, including internal notices to reduce overtime hours or fixed overtime pay. Moreover, attendance data may not necessarily reflect objective working hours in Japan particularly since the COVID-19 pandemic in 2020 where some people have started working at home, and their working hours may be close to self-reported, even if approved by their supervisors and personnel. Second, because this study was conducted at five Japanese firms, it is difficult to generalise the results. Moreover, the overall response rate was 45.9%, and we could not know the attributes of those who did not participate in the study; in our study, in order to ensure the participants' confidentiality, workers were asked to participate in the study through the employee assistance programme organisation by web survey, and only data of those who had given their consent to participate was delivered to us, so we have no information of whether the participants had not agreed to the current study or had simply not noticed the invitation to the survey. Although we considered AWH and number of long working hours from 6 months prior to the outcome measurement as exposure, the appropriateness of this exposure period remains unclear. The period of long working hours in Japan, which is an issue under Japanese workers' compensation, is 6 months; therefore, we used this as a reference. Another limitation is that we were unable to analyse participants' chronic health status. In other words, we observed only 6 months of working conditions, so reverse causality may be possible, such that a person who has a physical condition to begin with may not be able to work for long hours, or employees with depressive symptoms may take longer hours to do the same job than those without symptoms. In the future, we intend to assess workers' normal health conditions besides employment attributes using questionnaires. Moreover, several major factors that would possibly influence workers' stress responses, including demand-control-support, could not be included in this analysis because different companies used different scales of demand-control-support conditions. Furthermore, although we adjusted for the effects of COVID-19 emergency experiences in the analysis, psychological stress responses of workers who have and have not had COVID-19 may differ.

In conclusion, we examined the prospective relationship between objectively measured working-hour indicators (AWH/FLWH) for 6 months and workers' self-reported psychological/

physical stress responses measured in the subsequent month. We observed significant relationships between AWH/FLWH and workers' psychological stress responses. Notably, each psychological stress response increased with the different level of AWH/FLWH. Further, we did not identify any association between AWH/FLWH and physical stress responses. The present findings highlight that cumulative exposure to long working hours needs to be avoided to maintain mental health at work.

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Contributors MT, TM and TS designed the study. KF and TA collected the data. YOC analysed the data and prepared the first draft of the manuscript. YOC and MT interpreted the data, and MT, TM, TS, YS and YOT critically reviewed the manuscript. All authors read and approved the final version of the manuscript. MT is responsible for the overall content as a guarantor.

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Patient consent for publication Not applicable.

Ethics approval Participants were asked to participate in the study after explaining the purpose of the research. After explaining that participation in the study was completely voluntary, participants were asked to give their consent to participate in the study via an online screen. The Ethics Committee of the National Institute of Occupational Safety and Health, Japan (JNIOH) reviewed and approved the study protocol (Ethics committee approval No. H2812 and H2919).

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Supplemental Table 1 Distribution of attributes by average working hours

		Working hours categories (average of 6 months)											
		<140 h/mo		140–180 h/mo		180–205 h/mo		205–220 h/mo		≥220 h/mo		Total	
		(n=2,454)		(n=9,793)		(n=2,287)		(n=424)		(n=185)		(n=15,143)	
		n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)
Sex	Men	960	(39.1)	6305	(64.4)	1949	(85.2)	379	(89.4)	174	(94.1)	9767	(64.5)
	Women	1494	(60.9)	3488	(35.6)	338	(14.8)	45	(10.6)	11	(5.9)	5376	(35.5)
Age	≤29 years	407	(16.6)	1840	(18.8)	444	(19.4)	110	(25.9)	41	(22.2)	2842	(18.8)
	30–39 years	601	(24.5)	2431	(24.8)	634	(27.7)	132	(31.1)	53	(28.6)	3851	(25.4)
	40–49 years	548	(22.3)	2364	(24.1)	614	(26.8)	102	(24.1)	44	(23.8)	3672	(24.2)
	50–59 years	457	(18.6)	2115	(21.6)	480	(21.0)	70	(16.5)	45	(24.3)	3167	(20.9)
	≥60 years	441	(18.0)	1043	(10.7)	115	(5.0)	10	(2.4)	2	(1.1)	1611	(10.6)
Employment	Regular employee	490	(20.0)	7069	(72.2)	2139	(93.5)	413	(97.4)	184	(99.5)	10295	(68.0)
	Non-regular employee"	1964	(80.0)	2724	(27.8)	148	(6.5)	11	(2.6)	1	(0.5)	4848	(32.0)
Job type	Managerial	37	(1.5)	1747	(17.8)	651	(28.5)	103	(24.3)	49	(26.5)	2587	(17.1)
	Professional, technical, and Clerical	109	(4.4)	879	(9.0)	361	(15.8)	68	(16.0)	35	(18.9)	1452	(9.6)
	Sales & merchandising	336	(13.7)	1576	(16.1)	319	(13.9)	22	(5.2)	4	(2.2)	2257	(14.9)
	Sales & marketing	318	(13.0)	903	(9.2)	34	(1.5)	0	(0.0)	0	(0.0)	1255	(8.3)
	Service workers	75	(3.1)	1362	(13.9)	218	(9.5)	12	(2.8)	2	(1.1)	1669	(11.0)
	Transportation	1223	(49.8)	2040	(20.8)	128	(5.6)	9	(2.1)	1	(0.5)	3401	(22.5)
	Construction	20	(0.8)	17	(0.2)	8	(0.3)	1	(0.2)	0	(0.0)	46	(0.3)
	Production and technical workers	20	(0.8)	576	(5.9)	433	(18.9)	194	(45.8)	88	(47.6)	1311	(8.7)
	Others	49	(2.0)	119	(1.2)	21	(0.9)	5	(1.2)	2	(1.1)	196	(1.3)
Shift work	No	267	(10.9)	574	(5.9)	114	(5.0)	10	(2.4)	4	(2.2)	969	(6.4)
	Yes	2087	(85.0)	9180	(93.7)	2234	(97.7)	414	(97.6)	183	(98.9)	14098	(93.1)
COVID-19	No experience	367	(15.0)	613	(6.3)	53	(2.3)	10	(2.4)	2	(1.1)	1045	(6.9)
	Experience	1629	(66.4)	6714	(68.6)	1308	(57.2)	102	(24.1)	36	(19.5)	9789	(64.6)
		825	(33.6)	3079	(31.4)	979	(42.8)	322	(75.9)	149	(80.5)	5354	(35.4)

Supplemental_Table 2 Distribution of attributes by frequency of long working hours

		Frequency of long working hours (over 205 h/mo)						
		Zero (n=12,394)	Once (n=1,049)	Twice (n=617)	Three times (n=478)	Four times (n=392)	Five/Six times (n=213)	Total (n=15,143)
Sex	Men	7334 (59.2)	907 (86.5)	557 (90.3)	418 (87.4)	361 (92.1)	190 (89.2)	9767 (64.5)
	Women	5060 (40.8)	142 (13.5)	60 (9.7)	60 (12.6)	31 (7.9)	23 (10.8)	5376 (35.5)
Age	≤29 years	2227 (18.0)	216 (20.6)	146 (23.7)	111 (23.2)	91 (23.2)	51 (23.9)	2842 (18.8)
	30–39 years	3093 (25.0)	275 (26.2)	162 (26.3)	141 (29.5)	113 (28.8)	67 (31.5)	3851 (25.4)
	40–49 years	3028 (24.4)	266 (25.4)	141 (22.9)	99 (20.7)	95 (24.2)	43 (20.2)	3672 (24.2)
	50–59 years	2578 (20.8)	228 (21.7)	130 (21.1)	103 (21.5)	81 (20.7)	47 (22.1)	3167 (20.9)
	≥60 years	1468 (11.8)	64 (6.1)	38 (6.2)	24 (5.0)	12 (3.1)	5 (2.3)	1611 (10.6)
Employment type	Regular employee	7667 (61.9)	996 (94.9)	590 (95.6)	455 (95.2)	382 (97.4)	205 (96.2)	10295 (68.0)
	Non-regular employee	4727 (38.1)	53 (5.1)	27 (4.4)	23 (4.8)	10 (2.6)	8 (3.8)	4848 (32.0)
Job type	Managerial	1884 (15.2)	283 (27.0)	154 (25.0)	126 (26.4)	81 (20.7)	59 (27.7)	2587 (17.1)
	Professional, technical, and research	971 (7.8)	193 (18.4)	103 (16.7)	82 (17.2)	70 (17.9)	33 (15.5)	1452 (9.6)
	clerical	1966 (15.9)	140 (13.3)	83 (13.5)	44 (9.2)	18 (4.6)	6 (2.8)	2257 (14.9)
	Sales & merchandising	1227 (9.9)	20 (1.9)	4 (0.6)	2 (0.4)	1 (0.3)	1 (0.5)	1255 (8.3)
	Sales & marketing	1469 (11.9)	103 (9.8)	60 (9.7)	24 (5.0)	7 (1.8)	6 (2.8)	1669 (11.0)
	Service workers	3316 (26.8)	52 (5.0)	12 (1.9)	10 (2.1)	6 (1.5)	5 (2.3)	3401 (22.5)
	Transportation	39 (0.3)	2 (0.2)	2 (0.3)	3 (0.6)	0 (0.0)	0 (0.0)	46 (0.3)
	Construction	478 (3.9)	205 (19.5)	177 (28.7)	161 (33.7)	194 (49.5)	96 (45.1)	1311 (8.7)
	Production and technical workers	164 (1.3)	14 (1.3)	5 (0.8)	8 (1.7)	3 (0.8)	2 (0.9)	196 (1.3)
Others	880 (7.1)	37 (3.5)	17 (2.8)	18 (3.8)	12 (3.1)	5 (2.3)	969 (6.4)	
Shift work	No	11394 (91.9)	1032 (98.4)	606 (98.2)	470 (98.3)	386 (98.5)	210 (98.6)	14098 (93.1)
	Yes	1000 (8.1)	17 (1.6)	11 (1.8)	8 (1.7)	6 (1.5)	3 (1.4)	1045 (6.9)
COVID-19	No experience	8803 (71.0)	488 (46.5)	239 (38.7)	141 (29.5)	61 (15.6)	57 (26.8)	9788 (64.6)
	Experienced	3591 (29.0)	561 (53.5)	378 (61.3)	337 (70.5)	331 (84.4)	156 (73.2)	5354 (35.4)

Supplemental_Table 3 Association between average working hours for 6 months and stress response scores

		Crude model				Model 1 ^a				Model 2 ^b				
		Mear (SE) ^c	P-values	η^2 ^d	Multiple comparison ^e	Mear (SE)	P-values	η^2	Multiple comparison	Mear (SE)	P-values	η^2	Multiple comparison	
Vigor	I. <140 h/mo (<35 h/w)	2454	2.34 (0.02)	0.000	0.005	0.000	2.30 (0.02)	0.000	0.003	0.111	2.30 (0.02)	0.000	0.003	0.560
	II. 140–180 h/mo (35–45 h/w)	9793	2.25 (0.01)			ref ^f	2.25 (0.01)			ref	2.26 (0.01)			ref
	III. 180–205 h/mo(45–51.25 h/w)	2287	2.18 (0.02)			0.004	2.20 (0.02)			0.107	2.20 (0.02)			0.067
	IV. 205–220 h/mo (51.25–55 h/w)	424	2.08 (0.04)			0.000	2.10 (0.04)			0.002	2.08 (0.04)			0.000
	V. \geq 220 h/mo (\geq 55 h/w)	185	1.98 (0.06)			0.000	1.99 (0.06)			0.000	1.97 (0.06)			0.000
Irritability	I. <140 h/mo	2454	2.06 (0.02)	0.014	0.001	1.000	1.96 (0.02)	0.000	0.004	0.000	1.98 (0.02)	0.000	0.005	0.036
	II. 140–180 h/mo	9793	2.04 (0.01)			ref	2.04 (0.01)			ref	2.04 (0.01)			ref
	III. 180–205 h/mo	2287	2.05 (0.02)			1.000	2.12 (0.02)			0.000	2.12 (0.02)			0.000
	IV. 205–220 h/mo	424	2.16 (0.04)			0.027	2.21 (0.04)			0.000	2.25 (0.04)			0.000
	V. \geq 220 h/mo	185	2.14 (0.06)			0.775	2.22 (0.06)			0.030	2.26 (0.06)			0.001
Anxiety	I. <140 h/mo	2454	1.88 (0.02)	0.000	0.006	1.000	1.84 (0.02)	0.000	0.009	0.146	1.83 (0.02)	0.000	0.008	0.029
	II. 140–180 h/mo	9793	1.89 (0.01)			ref	1.89 (0.01)			ref	1.89 (0.01)			ref
	III. 180–205 h/mo	2287	1.96 (0.02)			0.000	2.01 (0.02)			0.000	2.01 (0.02)			0.000
	IV. 205–220 h/mo	424	2.17 (0.04)			0.000	2.19 (0.04)			0.000	2.17 (0.04)			0.000
	V. \geq 220 h/mo	185	2.15 (0.05)			0.000	2.19 (0.05)			0.000	2.17 (0.05)			0.000
Depressor	I. <140 h/mo	2454	1.72 (0.02)	0.000	0.005	0.001	1.75 (0.02)	0.000	0.002	0.385	1.77 (0.02)	0.000	0.003	1.000
	II. 140–180 h/mo	9793	1.78 (0.01)			ref	1.78 (0.01)			ref	1.78 (0.01)			ref
	III. 180–205 h/mo	2287	1.87 (0.02)			0.000	1.85 (0.02)			0.002	1.85 (0.02)			0.000
	IV. 205–220 h/mo	424	1.95 (0.04)			0.000	1.90 (0.04)			0.018	1.95 (0.04)			0.000
	V. \geq 220 h/mo	185	1.93 (0.05)			0.089	1.90 (0.05)			0.352	1.96 (0.05)			0.008
Fatigue	I. <140 h/mo	2454	2.19 (0.02)	0.000	0.007	0.000	2.02 (0.02)	0.000	0.003	1.000	2.04 (0.02)	0.000	0.004	1.000
	II. 140–180 h/mo	9793	2.04 (0.01)			ref	2.05 (0.01)			ref	2.05 (0.01)			ref
	III. 180–205 h/mo	2287	1.96 (0.02)			0.000	2.07 (0.02)			1.000	2.07 (0.02)			1.000
	IV. 205–220 h/mo	424	2.17 (0.04)			0.016	2.26 (0.04)			0.000	2.30 (0.04)			0.000
	V. \geq 220 h/mo	185	2.17 (0.06)			0.384	2.29 (0.06)			0.001	2.33 (0.06)			0.000
Physical complaint	I. <140 h/mo	2454	1.80 (0.01)	0.000	0.002	0.001	1.75 (0.01)	0.151	0.000	1.000	1.75 (0.01)	0.074	0.001	1.000
	II. 140–180 h/mo	9793	1.75 (0.01)			ref	1.75 (0.01)			ref	1.75 (0.01)			ref
	III. 180–205 h/mo	2287	1.71 (0.01)			0.037	1.76 (0.01)			1.000	1.76 (0.01)			1.000
	IV. 205–220 h/mo	424	1.79 (0.03)			1.000	1.82 (0.03)			0.134	1.83 (0.03)			0.052
	V. \geq 220 h/mo	185	1.73 (0.04)			1.000	1.78 (0.04)			1.000	1.79 (0.04)			1.000

a : Model 1: adjusted for sex, age, job type, employment type (regular employee or others), and work style (shift work or no shift work)

b: Model 2: adjusted for Model 1 and experience or no experience with COVID-19 emergencies in April 2020

c: SE, standard error

d: partial eta squared

e: Bonferroni method

f: ref, reference

Supplemental_Table 4 Relationship between frequency of long working hours and stress response scores

		Crude model					Model 1 ^a				Model 2 ^b			
		Mear (SE) ^c	p-values	η^2 ^d	Multiple comparison ^e	Mear (SE)	p-values	η^2	Multiple comparison	Mear (SE)	p-values	η^2	Multiple comparison	
Vigor	I. Zero	12394	2.27 (0.01)	0.000	0.005	ref ^f	2.27 (0.01)	0.000	0.003	ref	2.27 (0.01)	0.000	0.004	ref
	II. Once	1049	2.19 (0.03)			0.033	2.21 (0.03)			0.583	2.20 (0.03)			0.116
	III. Twice	617	2.16 (0.03)			0.021	2.18 (0.03)			0.191	2.16 (0.03)			0.026
	IV. Three times	478	2.14 (0.04)			0.008	2.16 (0.04)			0.082	2.13 (0.04)			0.005
	V. Four times	392	2.11 (0.04)			0.003	2.13 (0.04)			0.019	2.09 (0.04)			0.000
	VI. Five/six times	213	1.94 (0.06)			0.000	1.96 (0.06)			0.000	1.93 (0.06)			0.000
Irritability	I. Zero	12394	2.05 (0.01)	0.024	0.001	ref	2.04 (0.01)	0.000	0.002	ref	2.03 (0.01)	0.000	0.004	ref
	II. Once	1049	2.02 (0.02)			1.000	2.08 (0.02)			1.000	2.10 (0.02)			0.063
	III. Twice	617	2.02 (0.03)			1.000	2.07 (0.03)			1.000	2.10 (0.03)			0.290
	IV. Three times	478	2.07 (0.04)			1.000	2.12 (0.04)			0.290	2.17 (0.04)			0.002
	V. Four times	392	2.08 (0.04)			1.000	2.13 (0.04)			0.244	2.20 (0.04)			0.000
	VI. Five/six times	213	2.21 (0.05)			0.034	2.26 (0.05)			0.000	2.31 (0.05)			0.000
Anxiety	I. Zero	12394	1.88 (0.01)	0.000	0.008	ref	1.88 (0.01)	0.000	0.011	ref	1.88 (0.01)	0.000	0.009	ref
	II. Once	1049	1.94 (0.02)			0.230	1.98 (0.02)			0.000	1.98 (0.02)			0.001
	III. Twice	617	2.01 (0.03)			0.001	2.04 (0.03)			0.000	2.04 (0.03)			0.000
	IV. Three times	478	2.09 (0.03)			0.000	2.12 (0.03)			0.000	2.11 (0.03)			0.000
	V. Four times	392	2.17 (0.04)			0.000	2.19 (0.04)			0.000	2.17 (0.04)			0.000
	VI. Five/six times	213	2.17 (0.05)			0.000	2.20 (0.05)			0.000	2.18 (0.05)			0.000
Depression	I. Zero	12394	1.78 (0.01)	0.000	0.002	ref	1.79 (0.01)	0.112	0.001	ref	1.78 (0.01)	0.000	0.002	ref
	II. Once	1049	1.82 (0.02)			1.000	1.79 (0.02)			1.000	1.82 (0.02)			1.000
	III. Twice	617	1.84 (0.03)			0.767	1.81 (0.03)			1.000	1.85 (0.03)			0.377
	IV. Three times	478	1.88 (0.03)			0.089	1.84 (0.03)			1.000	1.89 (0.03)			0.014
	V. Four times	392	1.87 (0.04)			0.303	1.83 (0.04)			1.000	1.91 (0.04)			0.012
	VI. Five/six times	213	1.96 (0.05)			0.009	1.91 (0.05)			0.242	1.97 (0.05)			0.003
Fatigue	I. Zero	12394	2.07 (0.01)	0.000	0.003	ref	2.05 (0.01)	0.000	0.003	ref	2.04 (0.01)	0.000	0.004	ref
	II. Once	1049	1.93 (0.03)			0.000	2.04 (0.03)			1.000	2.06 (0.03)			1.000
	III. Twice	617	1.95 (0.03)			0.009	2.06 (0.03)			1.000	2.09 (0.03)			1.000
	IV. Three times	478	2.05 (0.04)			1.000	2.15 (0.04)			0.107	2.19 (0.04)			0.001
	V. Four times	392	2.09 (0.04)			1.000	2.19 (0.04)			0.015	2.24 (0.04)			0.000
	VI. Five/six times	213	2.25 (0.06)			0.033	2.34 (0.06)			0.000	2.38 (0.06)			0.000
Physical complaint	I. Zero	12394	1.76 (0.01)	0.013	0.001	ref	1.75 (0.01)	0.589	0.000	ref	1.75 (0.01)	0.343	0.000	ref
	II. Once	1049	1.71 (0.02)			0.104	1.76 (0.02)			1.000	1.76 (0.02)			1.000
	III. Twice	617	1.71 (0.02)			0.229	1.75 (0.02)			1.000	1.76 (0.02)			1.000
	IV. Three times	478	1.76 (0.03)			1.000	1.80 (0.03)			1.000	1.81 (0.03)			0.620
	V. Four times	392	1.71 (0.03)			1.000	1.76 (0.03)			1.000	1.77 (0.03)			1.000
	VI. Five/six times	213	1.75 (0.04)			1.000	1.79 (0.04)			1.000	1.80 (0.04)			1.000

a : Model 1: adjusted for sex, age, job type, employment type (regular employee or others), and work style (shift work or no shift work)

b: Model 2: adjusted for Model 1 and experience or no experience with COVID-19 emergencies in April 2020

c: SE, standard error

d: partial eta squared

e: Bonferroni method

f: ref, reference

Supplemental Material 1 – Details on BJSQ (Workers' self-reported stress responses)

[Instruction] Please answer the following questions concerning your health during the past month by circling the number that best fits your situation.

[options] 1: Almost never, 2: Sometimes, 3: Often, 4: Always often

Vigour	1	I have been very active
	2	I have been full of energy
	3	I have been lively
Irritability	1	I have felt angry
	2	I have been inwardly annoyed or aggravated
	3	I have felt irritable
Anxiety	1	I have felt tense
	2	I have felt worried or insecure
	3	I have felt restless
Depression	1	I have been depressed
	2	I have thought that doing anything was a hassle
	3	I have been unable to concentrate
	4	I have felt gloomy
	5	I have been unable to handle work
	6	I have felt sad
Fatigue	1	I have felt extremely tired
	2	I have felt exhausted
	3	I have felt weary or listless
Physical complaints	1	I have felt dizzy
	2	I have experienced joint pains
	3	I have experienced headaches
	4	I have had a stiff neck and /or shoulders
	5	I have had lower back pain
	6	I have had eyestrain
	7	I have experienced heart palpitations or shortness of breath
	8	I have experienced stomach and/or intestine problems
	9	I have lost my appetite
	10	I have experienced diarrhea and /or constipation
	11	I haven't been able to sleep well