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Original Article

Effort–reward imbalance at work and tooth loss: a cross-sectional study from the J-SHINE project

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Abstract: Oral diseases produce enormous productivity loss. However, epidemiological evidence of work stress and tooth loss is scarce. The aim of this study was to examine the association of work stress, according to effort–reward imbalance (ERI), with tooth loss. We conducted a cross-sectional study using data obtained between 2010 and 2011 in Japan. This study included 1,195 employees aged 25–50 years old (response rate=32%). The dependent variable was self-reported tooth loss (having or not). The independent variable was a dichotomized ERI ratio (>1.4 and ≤1.4). Age, sex, sociodemographic variables, work-related factors, and health-related variables were adjusted. Psychological distress was used as a potential mediator. We also examined an additive interaction between support from supervisors and ERI. The median age was 37, and 48% were women. After adjusting for the covariates, ERI was still associated with tooth loss (prevalence ratio=1.20 [95% confidence interval=1.01, 1.42] from Poisson regression models with a robust error variance). Psychological distress partially explained the association, and support from supervisors significantly attenuated the association. In conclusion, high ERI ratio was still associated with an increased risk of tooth loss among working adults.

Key words: Working environment, Oral health, Dental health, Effort-reward imbalance, Observational study

Introduction

Oral diseases such as caries and periodontal disease are a major public health problem due to the significant burden on quality of life[1)] and economics[2)]. Oral diseases also matter in occupational health because they lead to severe work productivity loss[2)]. Annual productivity loss due to oral diseases in 2015 was estimated at $187 billion worldwide[2)]. A recent Canadian study provided further evidence that over 40 million working hours were lost annually because of oral diseases and treatments among working-age individuals[3)]. Oral health also affects work performances in different ways, including a psychosocial mechanism: a hesitation to communicate with colleagues would decrease work productivity and affect teamwork. Furthermore, some people might have difficulty concentrating on their work, or have unsatisfactory sleep or rest because of severe pain due to oral diseases[4)]. Preventing or treating oral diseases is an important issue for workers and managers.

The effort–reward imbalance (ERI) model has been

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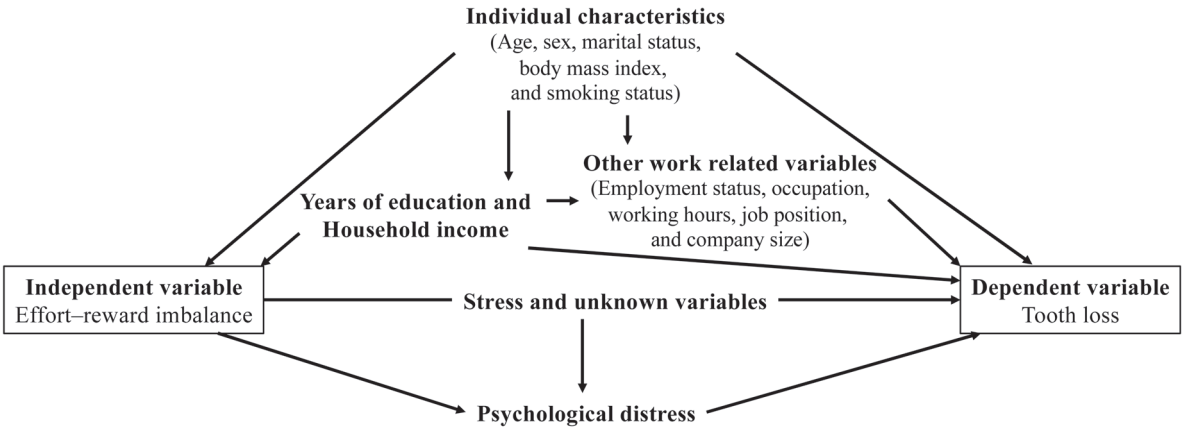

Fig. 1. The directed acyclic graph presenting the associations between effort–reward imbalance and tooth loss.

used to assess work-related stress[5]. Chronic stress can be linked to a decline in the immune system[6] and concomitant periodontal tissue destruction[7]. Dysfunction in the immune system or in periodontal tissue would be a risk factor for tooth loss; however, limited knowledge is available regarding the epidemiological association between work stress and oral health[8, 9].

Tooth loss is consequences of poor oral hygiene and oral diseases. Severe tooth loss accounted for 67% of global productivity losses due to oral health[2]. ERI brings about psychological distress[10]. Psychological distress is a cause of dysfunction in the immune system, decreasing salivary flow which can lead to caries and periodontal disease[8], and poor oral health behaviors such as less frequently toothbrushing[11]. Given that ERI has a negative effect on health by increasing psychological stress, ERI would cause tooth loss among workers due to high stress in the long run. Thus, we examined the hypothesis that ERI is associated with tooth loss.

We also tested another hypothesis that support from supervisors or colleagues might attenuate the harmful effect of ERI on oral health. The hypothesis was based on recent studies reporting that creating a cooperative working place with richer social support reduced the harmful effects of ERI on health[12, 13].

Subjects and Methods

Data sources and participants

We used data from the Japanese Study on Stratification, Health, Income, and Neighborhood (J-SHINE) project, the details of which are described elsewhere[14]. The survey was conducted between July 2010 and February 2011. Participants were community-dwelling adults aged 25–50 yr who were probabilistically selected from two municipalities in the Tokyo metropolitan area and two municipalities in neighboring prefectures. Appendix Fig. 1 shows the details in a flowchart of participants in the present study. Of the 13,920 people from the target population, 8,408 were invited to participate in the survey. Responses were obtained from 4,385 participants through questionnaires and interviews (response rate=32%). The aim was to explore the association of ERI with tooth loss, so the study population was restricted to actively working adults. We excluded 68 respondents who answered on behalf of actual participants, 83 who were not aged 25–50 yr old, 5 who did not answer the question on their sex, 1,298 who were not employed (a president or an executive officer, self-employed, housekeeper, subsidiary jobs, and member of the board) or did not answer the question, 1,568 who worked less than 20 h per wk or did not answer the question, 161 who had missing information in independent or dependent variables, 2 who had missing information in support from supervisors or coworkers, and 5 who belonged to categories with very few cases. Thus, the analytic population in this study was 1,195 participants.

Study design

This study was a cross-sectional study.

Independent variable: effort–reward imbalance ratio

We used the validated Japanese short version of the ERI questionnaire including 3 items of the effort scale (ranging from 3 to 13) and 7 items of the reward scale (ranging from 7 to 28)[15]. Two dimensions construct ERI: efforts spent at work and received societal rewards[5]. Efforts include components such as work pressure and immersion. Rewards include not only money but also esteem and

status control. ERI is assessed by a ratio score of the effort and reward scales adjusted for the unequal number of items in the two scales[15]. A high ERI ratio reflects a lack of reciprocity between efforts and rewards (high cost/low gain). The common theoretical cut-off point is 1.0[15]. A study provided that the cutoff point of 1.4 in the Japanese short version of the ERI is most equivalent to the cutoff point of 1.0 in the original version[15]. Therefore, we used the cutoff point of 1.4 and created a dichotomy variable (>1.4 and ≤1.4). In this study, each Cronbach's alpha was 0.794 in the effort scale and 0.772 in the reward scale.

Dependent variable: self-reported tooth loss

We assessed self-reported tooth loss using the following question: "How many teeth have you had removed or extracted (excluding tooth extraction for orthodontic treatment, wisdom tooth extraction, and primary teeth)?" Potential responses were "None," "1 tooth," "2 teeth," "3 teeth," "4 teeth," "more than 4 teeth," and "do not know" (missing value). We dichotomized these categories as having tooth loss or not (= no experience of tooth loss).

Covariates

We used the following sociodemographic variables as potential confounders and adjusted in models: age (25–29, 30–34, 35–39, 40–44, and 45–50 yr old), sex (men and women), marital status (married and single), years of education (≤12 and ≥13 yr), and annual household income (<5, ≥5 ≤7.5, and ≥7.5 million yen). We regarded following health-related variables as potential confounders: body mass index (<18.5, ≥18.5 ≤25.0, and ≥25.0 kg/m^2)[16] and smoking status (current smoker, former smoker, and never smoker). We also adjusted the following work-related factors, which would affect the association between ERI and oral health: employment status (regular and temporary employees), occupation (white-collar [e.g. professional, engineer, and office worker] and blue-collar [e.g., service worker, farmer, and factory worker]), job position (no title and manager: e.g. unit head and section chief), working hours per week (20 h to 39 h, 40 h to 49 h, and ≥50 h), and company size (number of employees) (<100, 100–999, and ≥1,000).

We supposed that psychological distress would mediate the association between ERI and tooth loss because ERI leads to psychological distress, which brings about oral diseases[7, 10]. Psychological distress was using the K6 (None [0–8] and Present [≥9])[17].

We assumed support from supervisors and coworkers as potential effect modifiers[12, 13]. Support from supervisors and co-workers was assessed using the Brief Job Stress Questionnaire, which has been validated in Japanese[18]. We calculated the sum of each question of support from supervisors and coworkers. Then, we dichotomized these variables using a median split (the median score was 8 in supervisors and 7 in coworkers).

Statistical analysis

We constructed a directed acyclic graph of proposed associations between ERI and tooth loss (Fig. 1). We conducted a Poisson regression analysis with a robust error variance to estimate prevalence ratios (PRs) of ERI for tooth loss and 95% confidence intervals (95% CIs). To verify the results from the analysis, we also conducted a negative binomial regression analysis using a number of teeth lost as a count variable. We created three models. In model 1, age and sex were adjusted; in model 2, we added annual household income, years of education, employment status, occupation, working hours per week, job position, company size, marital status, body mass index, and smoking status to model 1. In model 3, to confirm the potential pathway, we added psychological distress to model 2. Using Poisson regression models with a robust error variance, we assessed effect modifications on additive interactions and multiplicative interactions of support from supervisors and coworkers with ERI. To assess additive interactions, we calculated the relative excess risk due to interaction (RERI)[19]. If RERI >0, it indicates a positive additive interaction; if RERI <0, it indicates a negative additive interaction. To assess multiplicative interactions, we also examined the interaction term between ERI and support from supervisors and coworkers. We did not stratify the analysis by sex, because the multiplicative interaction term between sex and ERI was not significant (p=0.54). We created dummy variables for the missing values for each covariate. P-values <0.05 (two-tailed) were considered statistically significant. To calculate RERI, we used the Excel spreadsheet provided in the study[19], and other analyses were conducted using R version 3.5.0 with R studio version 1.0.153 in Macintosh.

Ethics approval and consent to participate

The ethics and informed consent procedure for the J-SHINE project were reviewed and approved by the ethics committee of the Graduate School of Medicine and Faculty of Medicine at The University of Tokyo. Informed consent was obtained in writing from all participants.

Results

The median age was 37 yr old with the 1st and 3rd quartiles being 31 and 43, respectively. The percentage of women was 48% (n=569). The percentages of ERI dichotomized at the cutoff point of 1.4 were 17% (n=207). The participants' characteristics are presented in Table 1. Participants with ERI tended to have tooth loss than participants without ERI.

Table 2 presents PRs and 95% CIs of ERI for tooth loss. In age- and sex-adjusted Poisson regression models with a robust error variance, ERI was associated with tooth loss (model 1: PR=1.26 [95% CI=1.06, 1.49]). After adjusting for covariates, we found participants with ERI had a high probability of having lost more teeth than participants without ERI (PR=1.20 [95% CI=1.01, 1.42]). In model 3, we observed changes in the associations between ERI and tooth loss after adjusting for psychological distress. The association decreased from model 2 to model 3 (model 3: PR=1.19 [95% CI=0.99, 1.43]). The results from negative binomial regression models were also consistent with ones from Poisson regression models with a robust error variance.

Tables 3 and 4 showed the additive and multiplicative interactions between ERI ratio and support from supervisors and coworkers, respectively. There were interactions between ERI and support from supervisors (RERI=0.68 [95% CI=0.33, 1.03], PR of the interaction term=2.07 [95% CI=1.24, 3.46]). High support from coworkers did not attenuate the association (RERI=0.11 [95% CI=−0.22, 0.45], PR of the interaction term=1.12 [95% CI=0.78, 1.59]).

Discussion

This is a first epidemiological study reporting the association between ERI and tooth loss using the cross-sectional data of employees aged 25−50 yr old in Japan. The associations of ERI and tooth loss were partly explained by psychological distress. Support from supervisors attenuated the negative association, and support from coworkers did not.

The current results are consistent with early studies. Since Marcenes and Sheiham have reported an association between job strain and periodontal disease in 1992[8], some evidence suggested that work stress potentially has a negative effect on self-rated oral health[9], periodontal diseases[20], and temporomandibular disorders[21]. However, some of these studies used non-specialized questions for work stress[20, 21]. Moreover, to the best of our knowledge, no studies examined associations between work stress and tooth loss. This study can add novel evidence indicating the association between work stress assessed by ERI and oral health.

Finding buffering factors would be of interest to managers and researchers. One solution would be to treat ERI itself, but this is sometimes difficult to tackle promptly. We also found another solution; managers can alleviate the harmful effect of ERI on oral health through social support. In fact, recent studies have provided alternative stress reduction approaches by creating cooperative environments through social support at the workplace[13]. Supervisors can positively change organizational environments such as increasing employee job satisfaction and organizational commitment[22]. Support from supervisors can buffer the associations between ERI and tooth loss. On the other hand, support from coworkers did not significantly interact the associations between ERI and tooth loss. Although coworkers are a common source of informational and emotional support[22], organizational environments are influenced more by supervisors rather than co-workers. The effect of support from coworkers on tooth loss showed a weaker association than that from supervisors.

There are some possible pathways between ERI and tooth loss. First, working stress could directly lead to tooth loss through negative physiological responses. The studies report the impacts of ERI on declines in the mucosal immune system[6] and increments in the inflammatory markers[23]. Periodontal disease is a chronic inflammatory disease in oral gums caused by microflora biofilms surrounding the teeth[7]. Periodontal disease is the second most common reason for tooth extraction in dental clinics[24, 25]. Therefore, work stress could lead to tooth loss due to destruction of periodontal tissue. Work stress is also potentially related to declines in saliva, which has functions to prevent caries[8]. Caries are the most common reason for tooth extraction[24, 25]. Work stress could also lead to tooth loss through severe caries. Second, there could be a psychological distress pathway. Work stress could cause psychological distress[26]. Psychological distress is also associated with unhealthy behaviors[27] and negative physiological responses such as declines in saliva[28]. Indeed, this possible mechanism was confirmed between models 2 and 3. Third, unhealthy behaviors and oral hygiene might also explain the association. ERI was associated with unhealthy behaviors[27]; therefore, ERI might also cause poor oral hygiene and oral health behaviors such as a less frequent tooth brushing. However, we were not able to obtain any information of oral health condition or

Table 1. Participants' characteristics and tooth loss according to effort–reward imbalance (n=1,195)

		Effort–reward imbalance ratio				*p*-value
		≤1.4 (n=988)		>1.4 (n=207)		
		n	(%)	n	(%)	
Age (yr)	25–30	203	(20.5)	40	(19.3)	0.48
	30–35	176	(17.8)	36	(17.4)	
	35–40	212	(21.5)	42	(20.3)	
	40–45	202	(20.4)	54	(26.1)	
	45–50	195	(19.7)	35	(16.9)	
Sex	Men	499	(50.5)	127	(61.4)	0.01
	Women	489	(49.5)	80	(38.6)	
Marital status	Married	654	(66.2)	129	(62.3)	0.32
	Single	334	(33.8)	78	(37.7)	
Annual household income (million yen)	<5	215	(27.7)	50	(31.6)	0.35
	≥5 – <7.5	224	(28.8)	49	(31.0)	
	≥7.5	338	(43.5)	59	(37.3)	
Years of education (yr)	≥13	785	(80.3)	152	(74.1)	0.06
	≤12	193	(19.7)	53	(25.9)	
Employment status	Regular employee	675	(68.3)	161	(77.8)	0.01
	Temporary employee	313	(31.7)	46	(22.2)	
Occupation	White-collar	743	(75.2)	153	(73.9)	0.76
	Blue-collar	245	(24.8)	54	(26.1)	
Working hours per week (h)	20–39	248	(25.1)	24	(11.6)	<0.01
	40–49	440	(44.5)	77	(37.2)	
	≥50	300	(30.4)	106	(51.2)	
Job position	No title	687	(69.5)	143	(69.1)	0.96
	Manager	301	(30.5)	64	(30.9)	
Company size (number of employees)	<100	295	(33.2)	79	(40.9)	0.10
	100–999	272	(30.6)	56	(29.0)	
	≥1,000	321	(36.1)	58	(30.1)	
Body mass index (kg/m^2)	≥25.0	86	(8.8)	16	(8.0)	0.14
	≥18.5 – <25.0	721	(73.8)	138	(68.7)	
	<18.5	170	(17.4)	47	(23.4)	
Smoking status	Current smoker	233	(23.6)	68	(32.9)	0.02
	Former smoker	227	(23.0)	38	(18.4)	
	Never smoker	528	(53.4)	101	(48.8)	
Psychological distress (K6)	None (0–8)	894	(90.5)	141	(68.1)	<0.01
	Present (≥9)	94	(9.5)	66	(31.9)	
Support from supervisors	High	507	(51.3)	51	(24.6)	<0.01
	Low	481	(48.7)	156	(75.4)	
Support from co-workers	High	448	(45.3)	66	(31.9)	<0.01
	Low	540	(54.7)	141	(68.1)	
Having tooth loss	Not	653	(66.1)	118	(57.0)	0.02
	Having	335	(33.9)	89	(43.0)	
Number of teeth lost	0	653	(66.1)	118	(57.0)	<0.01
	1	124	(12.6)	30	(14.5)	
	2	72	(7.3)	18	(8.7)	
	3	41	(4.1)	5	(2.4)	
	4	40.0	(4.0)	8.0	(3.9)	
	≥5	58.0	(5.9)	28.0	(13.5)	

The *p*-values were calculated by χ^2 test.

Table 2. Associations between effort–reward imbalance ratio and tooth loss from Poisson regression models with a robust error variance and negative binomial regression models (n=1,195)

	Model 1 (n=1,195)		Model 2 (n=1,195)		Model 3 (n=1,195)	
	PR	95% CI	PR	95% CI	PR	95% CI
Poisson regression models with a robust error variance						
ERI >1.4	1.26	1.06, 1.49	1.20	1.01, 1.42	1.19	0.99, 1.43
Negative binomial regression models						
ERI >1.4	1.45	1.11, 1.90	1.34	1.02, 1.76	1.28	0.97, 1.70

ERI was dichotomized at 1.4.

Model 1: Age and sex were adjusted.

Model 2: Model 1 + Marital status, annual household income, years of education, employment status, occupation, working hours per week, job position, company size, body mass index, and smoking status were adjusted.

Model 3: Model 2 + Psychological distress was adjusted.

ERI: effort-reward imbalance; PR: prevalence ratio; 95% CI: 95% confidence interval.

Table 3. Modification of the association between effort–reward imbalance and tooth loss by supervisors from Poisson regression models with a robust error variance (n=1,195)

		ERI				PRs (95% CI) of ERI (>1.4) from stratified models by support from supervisors	
		≤1.4		>1.4			
		PR	95%CI	PR	95%CI	PR	95%CI
Support from supervisors	High	1.00	-	0.69	0.43, 1.10	0.68	0.42, 1.09
	Low	0.87	0.73, 1.03	1.24	1.02, 1.50	1.47	1.20, 1.81
PRs (95% CI) of low support from supervisors from stratified models by ERI		0.86	0.73, 1.02	1.89	1.17, 3.05		

Measure of effect modification on additive scale: RERI (95% CI)=0.68 (0.33, 1.03); $p<0.01$.

Measure of effect modification on multiplicative scale: ratio of PR (95% CI)=2.07 (1.24, 3.46); $p=0.01$.

PRs are adjusted for age, sex, marital status, annual household income, years of education, employment status, occupation, working hours per week, job position, company size, body mass index, and smoking status.

ERI: effort-reward imbalance; PR: prevalence ratio; 95% CI: 95% confidence interval; RERI: relative excess risk due to interaction.

Table 4. Modification of the association between effort–reward imbalance and tooth loss by coworkers from Poisson regression models with a robust error variance (n=1,195)

		ERI				PRs (95% CI) of ERI (>1.4) from stratified models by support from co-workers	
		≤1.4		>1.4			
		PR	95%CI	PR	95%CI	PR	95%CI
Support from co-workers	High	1.00	-	1.11	0.83, 1.49	1.14	0.84, 1.55
	Low	0.92	0.78, 1.09	1.15	0.92, 1.44	1.27	1.03, 1.58
PRs (95% CI) of low support from coworkers from stratified models by ERI		0.92	0.77, 1.08	1.10	0.80, 1.51		

Measure of effect modification on additive scale: RERI (95% CI)=0.11 (−0.22, 0.45); $p=0.52$.

Measure of effect modification on multiplicative scale: ratio of PR (95% CI)=1.12 (0.78, 1.59); $p=0.54$.

PRs are adjusted for age, sex, marital status, annual household income, years of education, employment status, occupation, working hours per week, job position, company size, body mass index, and smoking status.

ERI: effort-reward imbalance; PR: prevalence ratio; 95% CI: 95% confidence interval; RERI: relative excess risk due to interaction.

behavior that would explain the association between ERI and tooth loss. Future studies should collect information on oral health condition or behavior such as toothbrushing and oral hygiene.

Limitations

The following limitations should be noted. First, the response rate was relatively low; however, the population of the J-SHINE survey was relatively similar to that of the target urban population with respect to age, sex, and educational qualification[14]. The current findings could be generalized to working adults in urban areas of Japan. Second, the causal inference is limited because the current study design was cross-sectional. A further cohort study is needed. Third, tooth loss was self-reported, and thus, the information might have some bias. Future studies should collect information on oral health as determined by dentists. Finally, the J-SHINE survey did not include adults over 50 yr old. Further study should include them.

Conclusions

We found associations between work stress measured by ERI and tooth loss, and they were partially mediated by psychological distress. Support from supervisors attenuated the negative associations between ERI and tooth loss. Managers should build a supportive work environment to buffer the negative impacts of ERI. In addition, oral diseases produce enormous burdens on work productivity and performance due to its high prevalence and declines in quality of life. Occupational specialists or managers should recognize the importance of oral health in the workplace and should note the need for oral health promotion among employees.

Authors' Contributions

YuS: conception and design, analysis and interpretation of data, and drafting the article. TT: acquisition of data, analysis and interpretation of data, and drafting the article. JA: acquisition of data and analysis and interpretation of data. YaS, EY, and KO: analysis and interpretation of data. All authors revised it critically and approved the final manuscript.

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Conflict of Interest

The authors declare no conflicts of interest.

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Appendix

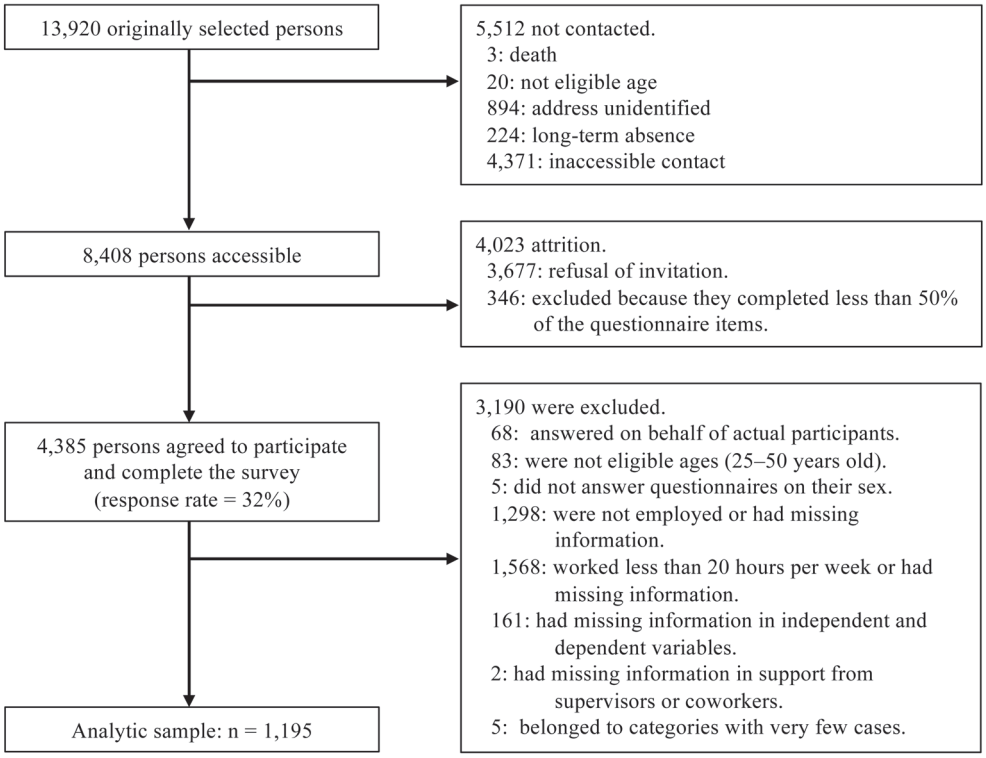

Fig. 1. The flowchart of the participants.