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Original Article

Relationship between days of work and presenteeism, and mediation of this relationship by fatigue among disaster responders

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Abstract

Objectives: Occupational health studies have identified positive associations between work duration and presenteeism, but there is limited understanding of this relationship in disaster responders. We examined the relationship between the number of work days and presenteeism and the mediating effect of fatigue in disaster responders deployed after the Noto Peninsula earthquake.
Methods: This cross-sectional study examined disaster responders deployed after the Noto Peninsula earthquake (Japan, 2024). Data were collected using the health management version of the app for Japanese Surveillance in Post-extreme Emergencies and Disasters, and included days of work, fatigue score, and presenteeism. Structural equation modeling (SEM) was employed to examine the direct and indirect effects of the number of work days on presenteeism, with fatigue as a potential mediator. Sensitivity analysis was also performed.
Results: We analyzed 4656 disaster responders who were deployed after the Noto Peninsula earthquake. Presenteeism increased with the number of work days, and ranged from 3.4% (1 day) to 16.9% (>7 days). However, fatigue decreased as the number of work days increased. SEM demonstrated a significant direct effect of the number of work days on presenteeism, and that fatigue slightly decreased this effect for work durations of 4 to 7 days and more than 7 days. Sensitivity analyses supported these findings.
Conclusions: Working more days led to increased presenteeism in disaster responders, but fatigue decreased as the number of work days increased. Future longitudinal studies should examine additional factors that may affect presenteeism in disaster responders and other individuals exposed to stressful environments.

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Key points

What is already known on this topic:
Many studies in occupational health have reported that employees working longer hours have a higher risk of presenteeism, in that these individuals experience pressure to continue working despite fatigue. Disaster responders working under stressful conditions are particularly vulnerable to decreased productivity due to fatigue. The disaster responders deployed after the Noto Peninsula earthquake (2024) participated in prolonged rescue operations that may have led to presenteeism and fatigue.

What this study adds:
This study analyzed data collected in real-time on the relationship of the number of work days, fatigue, and presenteeism in disaster responders following the Noto Peninsula earthquake. Longer work duration was associated with increased presenteeism, but fatigue partially mitigated this effect for those working more than 4 days. There are several possible explanations for the inverse relationship between days of work and fatigue, including the "healthy worker effect," in which responders who were most fatigued simply stopped working. We suggest that occupational health models that examine disaster responders can be refined by considering the nonlinear effect of fatigue.

How this study might affect research, practice, or policy:
Our results and analytical validation demonstrated that disaster responders who worked more days had a greater probability of presenteeism, but fatigue negatively mediated the association of work days and presenteeism for those working more than 4 days. Implementing regular health check-ups and monitoring for fatigue and presenteeism in disaster responders who work many consecutive days may help to ensure their well-being and the effectiveness of disaster operations.

Keywords: disaster responders; presenteeism; work duration; Noto Peninsula earthquake; J-SPEED.

Introduction

Natural and man-made disasters impose severe challenges on affected communities and the professionals who respond to these events.[1,2] In 2023, the world experienced 399 natural disasters that led to 86 473 fatalities, greater than the 20-year average of 64 148 per year.[3] These data underscore the immense burden that disasters impose not only on affected communities but also on responders, who face significant demands in delivering critical emergency relief services. Given these challenges, prioritizing responders' health, safety, and well-being is essential as their physical and mental resilience is crucial for their own protection, and for ensuring effective and sustained emergency response efforts in crisis situations.

Many studies and resources have examined the health of disaster victims, but the well-being of disaster responders is a critical yet underexamined issue. Disaster responders, including health care professionals, government officials, and humanitarian workers, play crucial roles in disaster mitigation and recovery.[4-6] However, their work often involves prolonged hours, intense physical exertion, and high psychological stress, all of which expose them to fatigue, stress, and presenteeism..[2,6] Fatigue in particular is a major concern as it directly affects cognitive function, decision-making, and physical performance, increasing the likelihood of errors and reduced efficiency in emergency response.[7] Presenteeism, where individuals continue working despite health impairments,[8] can also significantly compromise productivity, increase errors, and exacerbate health deterioration,[9-11] ultimately impacting both responders and those they assist.

There remains a critical gap in disaster research regarding how extended work hours and fatigue contribute to presenteeism among disaster responders. Understanding the interplay between work duration, fatigue, and presenteeism of disaster responders is essential to improve their health and responses to disasters. Such studies may help guide the development of work schedules that enhance the performance of these workers while protecting their health. Interventions that reduce fatigue and its consequences, and policies that balance operational demands with the well-being of responders can foster a more sustainable and resilient framework for disaster management.

These issues are particularly pressing in disaster-prone regions such as Japan, where frequent seismic events amplify the demands on disaster responders. The 2024 Noto Peninsula earthquake, which had a magnitude (M_L) of 7.6, struck Ishikawa Prefecture on January 1, 2024 and placed immense operational demands on disaster responders.[12,13] This event highlights the need to understand the factors influencing responders' health and performance under extreme conditions. Therefore, the present study examined the relationship between the number of days of work and presenteeism in these disaster responders, and the possible effect of fatigue as a mediating factor.

Methods

Context of the study

The 2024 Noto Peninsula earthquake occurred on January 1, 2024, and triggered a tsunami that severely impacted adjacent coastal areas, particularly Iida Bay.[14] This earthquake led to the opening of more than 1300 evacuation centers that cared for more than 52 000 evacuees.[15] As of December 24, 2024, this earthquake was responsible for an estimated 489 deaths, 1379 injuries, and damage to 149 724 houses.[16] More than 2518 Japanese emergency medical teams (EMTs) provided medical consultations after this earthquake.[17]

Study design and study participants

Following the earthquake, disaster responders were deployed to the affected areas on January 1, 2024, to provide medical care for disaster victims. These responders were primarily external personnel, including members of the Japanese Disaster Medical Assistance Team, the Red Cross, nongovernmental organizations, and volunteers from other prefectures. Additionally, a smaller proportion of local responders, such as local health care workers and community volunteers, also contributed to the disaster response efforts.

To monitor health-related problems of these responders, the Ishikawa Emergency Medical Team Coordination Cell (EMTCC) began data collection on January 1, 2024, and continued until March 31, 2024. Previously, EMTCC had collected health data only from disaster victims. However, this was the first time that comprehensive data were collected from disaster responders during the aftermath of a disaster.

To facilitate data collection, EMTCC used the health management version of the app for the Japanese Surveillance in Post-extreme Emergencies and Disasters (J-SPEED+ app). This tool was originally developed to collect data from patients visiting EMTs during disasters,[18] and was adapted to focus specifically on responders to this disaster.

To ensure proper data entry, EMTCC conducted on-site hands-on training, distributed user manuals, and offered continuous guidance to responders if necessary. Although the J-SPEED+ app was launched on January 1, initial data entry was minimal because of the limited number of responders present in the first few days. However, as more personnel arrived, the data collection became progressively more consistent. Ongoing guidance was provided for new arrivals to ensure proper reporting.

All responders were required to register their team's name and phone number when signing up for the J-SPEED+ app and were asked to use this app to enter daily health information using predefined checkboxes. The data collection framework consisted of 46 predefined items defined by the National Research Committee and other experts, categorized into 8 key sections: organization name, type of occupation, type of activity, environmental problems, symptoms, work performance, fatigue, and consultation requests. For this analysis, we focused on fatigue scores, Work Functioning Impairment Scale–Disaster Version (WFun-D) scores, type of occupation, type of activity, reported symptoms, and self-reported environmental conditions. Moreover, we classified the disaster response period into 2 phases, the first half and the second half, to examine potential variations over time.

Although these data were collected over 2 months and disaster responders had varying consecutive work days, this study remains a cross-sectional study because of the relationship between variables at a single aggregated time point. The analysis was based on each responder's longest consecutive work days rather than tracking changes over time.

Main variables used for the analysis

The primary outcome variables were the number of consecutive work days, self-reported fatigue, and presenteeism. The confounding variables were occupation, type of activity, disaster phase, symptoms, and self-reported environmental problems. Disaster responders may have multiple deployments throughout the entire response period, and there may be different numbers of work days during each deployment. Thus, for each disaster responder, the deployment period with the greatest number of consecutive work days was used for analysis. If a disaster respondent had multiple deployments with the same duration of work days, the earliest deployments were used.

To monitor the health of disaster responders and facilitate proactive preventive measures, fatigue levels were assessed using a 10-point scale, in which 1 indicated minimal fatigue and 10 represented extreme fatigue. This scale was based on the Visual Analogue Scale (VAS) for fatigue developed by the Japan Society of Fatigue.[19] Responders recorded daily perceived fatigue scores, and the average score during the period with the most consecutive days at work was then calculated.

Presenteeism was measured using the WFun-D. This scale was adapted from the original 7-item WFun,[20] which uses a Likert scale and was developed by the University of Occupational and Environmental Health, Japan. The WFun-D was subsequently simplified to 5 yes/no questions by the National Research Committee and other experts, including the WFun developer, to create a simple and effective tool. The total score of the WFun-D ranged from 0 (no presenteeism) to 5 (high presenteeism). Given the low percentage of responders who scored above 1, a score of 1 or higher was used to indicate presenteeism in this study.

Statistical analysis

Structural equation modeling (SEM) was used to identify whether the number of consecutive work days (X) was associated with presenteeism (Y), and the effect of self-reported fatigue (M) as a mediator (Figure 1). To categorize the number of work days, 1 day was used as the reference, and 3 categorical variables were then created: 2-3 days (D_1), 4-7 days (D_2), and more than 7 days (D_3). These durations were based on the 25th, 50th, and 75th percentiles of the data distribution.

First, a linear regression model was used to estimate the impact of consecutive work days on fatigue:

$$\mathrm{M_i} = \alpha + \alpha_1 \mathrm{D_{1i}} + \alpha_2 \mathrm{D_{2i}} + \alpha_3 \mathrm{D_{3i}} + \varepsilon \mathrm{M_i} \quad (1)$$

where M_i is the fatigue score for individual i; α is the intercept; α_1, α_2, α_3 are the coefficients for each category (D_1, D_2, D_3), and represent the difference in mean fatigue score relative to the reference category (1 day); and εM_i is the residual error term.

Next, a logistic regression model for presenteeism (Y), which included the direct effect of the number of work days (X) and the mediating effect of fatigue (M), was applied:

$$Logit\ (\mathrm{P}(\mathrm{Y_i} = 1)) = \beta + \beta_1 \mathrm{D_{1i}} + \beta_2 \mathrm{D_{2i}} + \beta_3 \mathrm{D_{3i}} + \mathrm{bM_i} + \varepsilon \mathrm{Y} \quad (2)$$

where β is the intercept on the log-odds scale; β_1, β_2, β_3 are the direct-effect coefficients for each category (D_1, D_2, D_3) on presenteeism relative to the reference category (1 day) when controlling for fatigue (M); b is the coefficient representing the effects of fatigue (M) on presenteeism (Y); and εY is the residual error term.

For the 3 categories of work days (D_1, D_2, and D_3), the following 3 effect estimates were calculated relative to the reference (1 day): (1) indirect effect (effect mediated by fatigue, calculated as $\alpha k \times b$, where αk is the effect of the number of work days on fatigue and b is the effect of fatigue on presenteeism); (2) direct effect (βk, the effect of X on Y independent of M); and (3) total effect ($\beta k + \alpha k \times b$), where k corresponds to each of the categories (Figure 1). The final models were adjusted according to type of activity, occupation, presence of symptoms, and self-reported environmental problems at work.

All analyses were conducted in R using the lavaan package. Because presenteeism (Y) was treated as a binary variable, a logistic link was established by setting ordered = "Y" and link = "logit." The estimation was made using diagonally weighted least squares, because this approach can provide a more robust analysis of noncontinuous outcomes than standard maximum likelihood estimation.[21] To ensure more reliable estimates of the SEs and CIs, particularly for the indirect (mediated) effects, a bootstrap procedure was used with 5000 resamples. This approach helps account for the nonnormal sampling distribution of the product of paths.[22,23] An effect was considered statistically significant if its 95% CI did not include 0 on the log-odds scale, or 1 when analyzing exponentiated odds ratios.

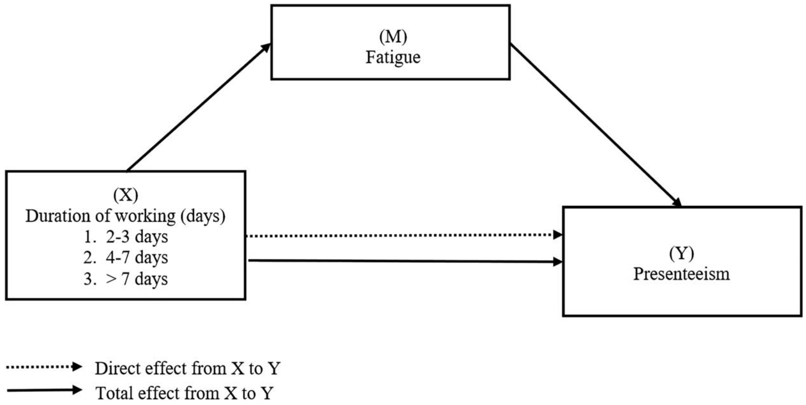


Figure 1. Structural equation model used to examine the relationship between the number of consecutive work days and presenteeism, and the mediating effect of fatigue in disaster responders.

Model convergence and fit were assessed via standard SEM indices, including χ^2, comparative fit index (CFI), Tucker-Lewis index (TLI), and root mean square error of approximation (RMSEA). Sensitivity analysis was performed using linear SEM, in which the number of work days (X) was treated as a continuous variable and was regressed on presenteeism (Y) and fatigue (M). Although fatigue was measured on a continuous scale (range: 1-10), its impact on presenteeism might not be linear; for example, increasing the number of work days from 1 to 2 could have a small effect, but increasing the number of work days from 4 to 5 might have a large effect. Therefore, the use of categories of work days allowed the effect to differ among ranges by identifying stepwise differences, which cannot be identified using a continuous model. Thus, analyses using continuous and categorical approaches can help demonstrate whether an observed effect depends on the coding of a predictor, because it considers the potential nonlinear relationships among number of work days, fatigue, and presenteeism.

Ethical considerations

This study was approved by the Ethical Committee of Hiroshima University (approval number: E2024-0120). Because this was a real-time study of a disaster, explicit informed consent was not obtained from disaster responders, and all data were anonymized before analysis.

Results

We examined 4656 individuals who worked as disaster responders after the Noto Peninsula earthquake (January 1, 2024) and collected data until March 31, 2024 (Table 1). Significant numbers of these disaster responders were nurses ($n = 1415$, 30.4%), logisticians ($n = 1332$, 28.6%), and doctors ($n = 1009$, 21.7%). About one-fourth (24.6%) were employed at a health emergency operation center, where they provided support and management for the disaster response. Among all responders, 41.1% worked for a maximum of 2 to 3 consecutive days, and 38.1% worked for a maximum of 4 to 7 consecutive days. A total of 148 (3.2%) responders reported physical or mental symptoms, and 93 (2.1%) reported adverse environmental conditions. A total of 279 responders (6.1%) reported presenteeism, and the rate of presenteeism increased with work duration (3.4%: 1 day; 6.1%: 2-3 days; 6.9%: 4-7 days; 16.9%: >7 days).

We also analyzed the fatigue scores of disaster responders according to the number of work days (Figure 2). The results demonstrate a gradual decrease of the mean fatigue score and its SD as the number of work days increased.

The results of the SEM also show that work duration had a direct effect on presenteeism (Table 2). Thus, compared with the reference group (1 day), the odds of presenteeism were significantly greater for responders working 2 to 3 days (odds ratio [OR] = 1.44; 95% CI, 1.18-1.75), 4 to 7 days (OR = 1.56; 95% CI, 1.28-1.91), and more than 7 days (OR = 2.89; 95% CI, 1.94-4.32). In addition, fatigue moderated this effect, in that it was associated with decreased presenteeism for work durations of 4 to 7 days (OR = 0.96; 95% CI, 0.94-0.99) and more than 7 days (OR = 0.86; 95% CI, 0.79-0.95). In other words, fatigue partially reduced the direct effect of long work duration on presenteeism. The total of direct and indirect effects indicated that the OR of presenteeism was 1.44 for responders working 2 to 3 days, 1.51 for responders working 4 to 7 days, and 2.49 for responders working more than 7 days. The final model demonstrated an excellent fit to these data, with a CFI of 0.979, TLI of 0.995, RMSEA of 0.015 (95% CI, 0.000-0.030), and SRMR of 0.002.

We also performed a sensitivity analysis, in which work duration was treated as a continuous variable (Table 3). The total effect (OR = 1.03; 95% CI, 1.01-1.04; $P < .001$) and direct effect (OR = 1.04; 95% CI, 1.02-1.05; $P < .001$) indicated a modest but statistically significant positive association of number of work days with presenteeism, consistent with the results from the categorical model (Table 2). The indirect (fatigue-mediated) effect had a minor negative association with presenteeism (OR = 0.993; 95% CI, 0.988-0.997; $P < .001$), somewhat inconsistent with the results from the categorical model (Table 2; OR = 0.96 for 4-7 days, OR = 0.86 for >7 days). This small difference likely arises from differences in model specification: the continuous model smoothed effects across all days, but the categorical model captured larger differences for more work days. Nonetheless, the model fit remained excellent, with a CFI of 0.975, TLI of 0.994, RMSEA of 0.016, and SRMR of 0.002, supporting the general trends identified in the categorical model.

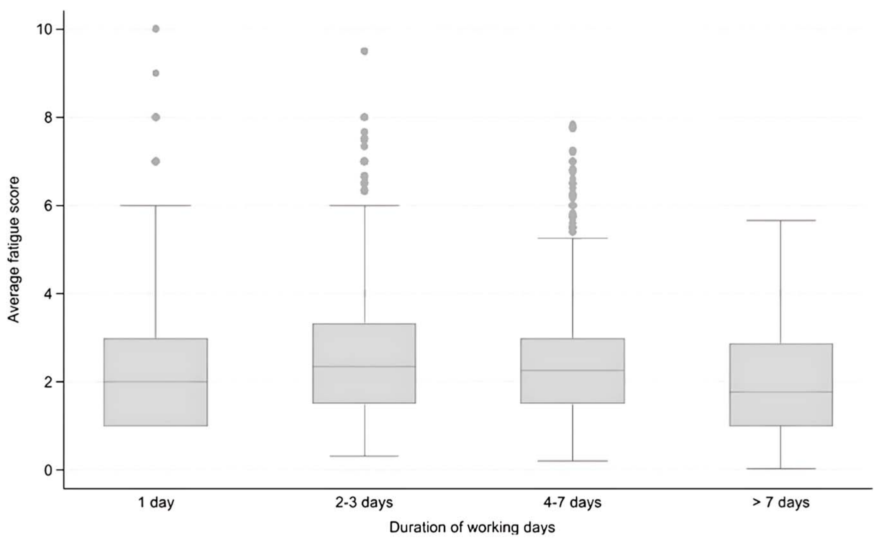
Discussion

This study examined the relationship between the number of consecutive work days and presenteeism in disaster responders who were deployed after the 2024 Noto Peninsula earthquake in Japan. The overall prevalence of presenteeism was 6.1%, and presenteeism was more common in those who worked more days. We also found a negative association between the

Table 1. Characteristics of disaster responders deployed after the Noto Peninsula earthquake.

Variable	All study participants		Participants reporting presenteeism		Participants not reporting presenteeism	
	Number	Percent[a]	Number	Percent[b]	Number	Percent[b]
Total	4656	100	279	6.1	4305	93.9
Number of working days						
1	894	19.2	29	3.4	814	96.6
2-3	1912	41.1	115	6.1	1787	94.0
4-7	1773	38.1	122	6.9	1640	93.1
>7	77	1.7	13	16.9	64	83.1
Occupation						
Doctor	1009	21.7	65	6.5	930	93.5
Nurse	1415	30.4	86	6.2	1302	93.8
Logistician	1332	28.6	86	6.5	1231	93.5
Other	900	19.3	42	4.8	842	95.3
Activity						
Health Emergency Operation center	1145	24.6	95	8.4	1041	91.6
Non–Health Emergency Operation center	3511	75.4	184	5.3	3264	94.7
Disaster phase						
Phase I (January 1 to February 15)	3716	79.8	248	6.8	3413	93.2
Phase II (February 16 to March 31)	940	20.2	31	3.4	892	96.6
Physical or mental symptoms						
No	4456	96.8	258	5.9	4128	94.1
Yes	148	3.2	16	10.9	131	89.1
Perception of working environment						
Having a problem	4398	97.9	240	5.5	4110	94.5
Not having a problem	93	2.1	30	32.6	62	67.4

[a]Column percent.
[b]Row percent.



Note1: Average fatigue score (mean ± standard deviation) - 2.69 ± 1.70 in 1 day, 2.64 ± 1.43 in 2–3 days, 2.52 ± 1.30 in 4–7 days, 2.19 ± 1.33 in >7 days.
Note2: Each box indicates median and interquartile range [IQR], upper and lower horizontal bars indicate [maximum and minimum values within 1.5 times the IQR (or the data range)], and filled circles indicate [Outliers].

Figure 2. Effect of the number of consecutive work days on fatigue score in disaster responders.

number of work days and fatigue. Overall, these findings provide valuable insights into how extended durations of work can affect the function of disaster responders. The prevalence of presenteeism among these disaster responders was relatively low compared with those in similar occupations,[24,25] possibly because these disaster responders had a strong sense of professional responsibility and understood the need to support victims. During the acute phase of the response to this earthquake, disaster responders forfeited their New Year's vacations to engage in life-saving activities,[12] demonstrating a serious commitment and understanding of the critical nature of their roles.

We initially hypothesized that more consecutive work days would lead to greater fatigue, which would increase the likelihood of presenteeism, as in previous studies that were conducted in general occupational health settings.[26-29] However, our results showed that fatigue was lower in those who worked 4 days or more. Nonetheless, the number of work days increased the

Table 2. Effect of the number of consecutive work days on presenteeism, and the mediating effect of fatigue, in disaster responders.

	Adjusted OR[a]	95% CI	P value	Bootstrapping	
				0.025 CI	0.975 CI
Model pathways					
Total effect: X → Y					
1 day	Reference				
2-3 days	1.44	(1.18–1.77)	<.001	1.15	1.75
4-7 days	1.51	(1.23–1.85)	<.001	1.24	1.87
>7 days	2.49	(1.66–3.75)	<.001	2.58	5.35
Direct effect: X → Y					
1 day	Reference				
2-3 days	1.44	(1.18–1.75)	<.001	1.14	1.73
4-7 days	1.56	(1.28–1.91)	<.001	1.30	2.04
>7 days	2.89	(1.94–4.32)	<.001	2.73	6.38
Indirect effect: X → M → Y					
1 day	Reference				
2-3 days	1.01	(0.98–1.03)	.667	0.97	1.07
4-7 days	0.96	(0.94–0.99)	.014	0.85	0.99
>7 days	0.86	(0.79–0.95)	.002	0.67	0.98
Model fitness measure					
Model test Baseline Model		0.090			
Comparative Fit Index (CFI)		0.979			
Tucker-Lewis Index (TLI)		0.995			
RMSEA		0.015 (0.000–0.030)			
SRMR		0.002			

Abbreviations: M, fatigue; OR, odds ratio, RMSEA, root mean square error of approximation; SRMR, standardized root mean square residual; X, duration of working days; Y, presenteeism.
[a]OR was adjusted for occupation, type of activity, disaster phase, physical or mental symptoms, and perception of the working environment.

Table 3. Sensitivity analysis of the effect of the number of consecutive work days on presenteeism, and the mediating effects of fatigue, in disaster responders.

	Adjusted OR[a]	95% CI	P value	Bootstrapping	
				0.025 CI	0.975 CI
Model pathways[b]					
Total effect: X → Y	1.03	1.01–1.04	<.001	1.02	1.07
Direct effect: X → Y	1.04	1.02–1.05	<.001	1.01	1.06
Indirect effect: X → M → Y	0.993	0.988–0.997	<.001	0.987	0.995
Model fitness					
Model test Baseline Model		0.073			
Comparative Fit Index (CFI)		0.975			
Tucker-Lewis Index (TLI)		0.994			
RMSEA		0.016 (0.000–0.031)			
SRMR		0.002			

Abbreviations: M, fatigue; OR, odds ratio, RMSEA, root mean square error of approximation; SRMR, standardized root mean square residual; X, duration of working days; Y, presenteeism.
[a]OR was adjusted for occupation, type of activity, disaster phase, presence of physical or mental symptoms, and perception of the working environment.
[b]Independent variable (working duration) was modeled as a continuous variable.

probability of presenteeism, even after accounting for the moderating effect of fatigue.

The association between work duration and presenteeism is likely to be affected by context and cultural factors. In the context of a disaster response, presenteeism is particularly pronounced due to the urgency of the situation, and this compels responders to continue working regardless of their physical, mental, or emotional state.[30] Implicit or explicit norms within disaster response teams frequently encourage these workers to ignore minor illnesses or fatigue to ensure that critical tasks are completed. This internal, peer-driven pressure increases with the number of work days, further perpetuating presenteeism.[28,31] Thus, in high-stress disaster settings, teams often develop a "tough it out" culture. Over time, these group norms grow stronger, pushing members to keep working even when they are unhealthy and less productive.[32] Moreover, staffing shortages and high workloads during disasters leave few opportunities for responders to take time off. The longer responders work, the more aware they become of the importance of each team member's contributions, leading to a "can't afford to stay home" mindset.[31] This situation is more severe for individuals with highly specific roles, such as specialized medical staff, who cannot easily be replaced.

In terms of cultural factors, a strong sense of duty often drives disaster responders to remain at work, even when unwell, because they perceive the mission as critical.[29] Many responders work additional days to maintain group harmony and meet shared expectations, reinforcing this behavior. The feeling of an obligation to remain on the job is further amplified during severe emergencies and crises. Responders who work more often see themselves and others as indispensable in these settings.[31] In addition, over time, a responder may develop a strong personal identity as a frontline worker, and interpret an illness or taking time off as a sign of weakness or failure. This self-imposed expectation, combined with the reluctance of shifting their workload onto already overburdened colleagues, reinforces the "keep going no matter what" attitude.[32,33]

We can suggest some possible explanations for the inverse relationship between work duration and fatigue. Disaster responders, particularly members of an EMT, are frequently trained to manage extended work durations. They may have adaptations that prevent them from experiencing (or disclosing) fatigue, even after many consecutive work days.[32] Another research group also revealed that self-reported fatigue levels may be influenced by factors such as adaptation or perceptual bias, which could lead to a divergence between subjective perceptions and objective physiological indicators over time.[34] Moreover, many disaster responders are motivated by a strong sense of commitment and altruism, leading to an "adrenaline rush," so they feel energized and report lower levels of fatigue.[35] Furthermore, the inverse relationship of work duration and fatigue may be attributed to the "healthy worker effect,"[36] in which individuals who are healthier and have greater physical or mental resilience are more likely to work more days and report less fatigue.[37] Over time, workers who experience significant fatigue or injuries tend to stop working or reduce their workload, leaving a truncated sample of workers with low fatigue but many work days.[38] Another possible explanation is the role of effective management in ensuring adequate rest intervals. If team managers implement well-structured schedules with sufficient breaks, responders working for longer durations may experience less fatigue because they are better rested, despite working more days. Conversely, individuals with shorter but more intense work shifts, such as in high-pressure scenarios, may develop fatigue even though their work periods are shorter.[39] This finding aligns with a study conducted among EMT members during the G7 Hiroshima Summit 2023,[37] which reported higher levels of fatigue during the first and second days of deployment compared with the third, fourth, and fifth days.

When we performed SEM using the number of work days as a categorical variable, fatigue partially moderated the positive relationship between work days and presenteeism, especially for the categories of 4 to 7 days and more than 7 days. In contrast, when we performed SEM using the number of work days as a continuous variable, fatigue had a small and nearly negligible effect. This suggests that fatigue had a more significant effect when there are 4 or more work days, but the overall average effect of fatigue was small.

This study had several strengths and limitations. The main strength is that it is, to our knowledge, the first report of daily real-time data collected from disaster responders who were deployed after an earthquake. Most previous studies focused on disaster victims. Another strength is that we used a large sample of disaster responders, which allowed for more robust statistical analysis. However, the limitations of this study are that we did not account for sociodemographic characteristics (age, sex, marital status, working years, and work experience); these and other factors may have influenced presenteeism. Second, our use of self-reported scores for presenteeism and fatigue could have led to social desirability bias, because disaster responders may have downplayed their fatigue due to the perception that fatigue is a weakness or overstated their ability to continue working under extreme conditions. The timing of data collection (eg, after a rest period, immediately after a strenuous shift, etc) may also have influenced fatigue scores. Third, it was assumed that the sequence of consecutive working days was interrupted if there were more than 2 missing days. This approach did not account for the possibility that disaster responders may have continued working but failed to enter data. As a result, the duration of working days might not accurately reflect the actual work days and fatigue scores of the responders.

Future research should consider the use of longitudinal follow-up studies to track disaster responders in the aftermath of a deployment. Such studies could assess whether coping strategies remained effective in the aftermath of a disaster and explore the potential effect of accumulated fatigue and disaster-related exhaustion over time. To improve the accuracy of measuring presenteeism, future research should also focus on validating the WFun-D scale, specifically by disaster responders during deployment. This validation process should ensure that the scale accurately captures presenteeism in high-stress, resource-constrained environments. Self-reported fatigue measurement is cost-effective, noninvasive, and easy to administer—making it practical for large-scale research, particularly in disaster contexts. However, future research could explore the distinction between perceived fatigue and its potential physiological manifestations by integrating self-reports with objective measures such as physiological markers (eg, heart rate variability, electroencephalography, cortisol), performance-based tasks (eg, psychomotor vigilance tests, reaction time assessments), and wearable or behavioral tracking (eg, actigraphy, eye-tracking).

Practical implications

The findings of this study of disaster responders who were deployed after an earthquake highlight the importance of occupational health interventions for mitigating the impact of long work periods. Given the positive association between the number of work days and presenteeism, we suggest that targeted interventions should prioritize responders who are deployed for longer durations. Implementing structured health check-ups and regular monitoring during extended deployments can potentially identify early signs of fatigue and presenteeism, reduce the risk of accidents and injuries, and ensure the well-being and effectiveness of disaster responders.

Conclusion

This study provides valuable insights into the relationship between work duration, fatigue, and presenteeism in disaster responders who were deployed after the 2024 Noto Peninsula earthquake. The findings highlight that a greater number of consecutive work days was associated with increased presenteeism, thus emphasizing the need for targeted interventions to support the well-being of disaster responders. Although we expected that long consecutive work days would increase fatigue, which in turn increases the higher odds of presenteeism, we found an inverse association between the number of work days and fatigue. These results suggest that factors such as adaptive coping strategies and psychological resilience may play a role in shaping the perception of fatigue in disaster responders. Future longitudinal studies may help to clarify the multifaceted drivers of presenteeism in high-stress environments.

Author contributions

I.-K.K., O.C.-O., and T.K. conceived the ideas; T.N., O.H., A.T., and N.S. contributed to the data collection; I.-K.K., O.C.-O., and E.M.R. analyzed the data; I.-K.K. and O.C.-O. drafted the original manuscript; I.-K.K., O.C.-O., E.M.R., S.T., N.E., K.M., Y.F., and T.K. edited the manuscript; I.-K.K., O.C.-O., E.M.R., S.T., N.E., K.M.,Y.F., Y.Y., A.F., T.N., O.H., A.T., N.S., and T.K. reviewed the manuscript. All authors have read and agreed to the published version of this manuscript.

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Conflicts of interest

The authors have no relevant interests to declare.

Data availability

Restrictions apply to the availability of these data. Data were obtained from the J-SPEED Research Group and Hiroshima University Ethical Committee for research purposes and are available with the permission of J-SPEED Research Group and Hiroshima University Ethical Committee.

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