Prevalence and risk factors associated with poor sleep among firefighters in Taiwan
An observational study
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Abstract
Sleep quality is directly correlated with overall health and quality of life. Firefighters have a higher workload and injury rate than those in other occupations. This study investigated the prevalence of and risk factors for poor sleep quality among firefighters in Taiwan. This cross-sectional study was conducted between November 2019 and August 2020. Sociodemographic information of the study participants was collected using a structured self-administered questionnaire. The Chinese version of the Pittsburgh Sleep Quality Index (PSQI) was used to evaluate the subjective sleep quantity and quality of firefighters during the previous month. A t test for continuous variables and χ² test for categorical variables were performed for univariate analysis. Logistic regression analysis was conducted for multivariate analysis. Eight hundred eighty-nine firefighters completed the questionnaire during the study period, with a response rate of 88.9%. Among them, 447 (50.3%) reported poor sleep quality. Logistic regression analysis showed that female sex, longer work duration (>5 years) for firefighters, on-call shift work, and no leisure-time physical activity (LTPA) was significantly correlated with an increased risk of poor sleep quality. Advanced analysis of partaking in LTPA revealed that high-intensity LTPA is significantly associated with higher rates of poor sleep quality. In contrast, adequate rest after LTPA correlated with lower rates of poor sleep quality. Firefighters are at higher risk of poor sleep quality. Emphasis should be placed on firefighters’ regular LTPA, particularly when experiencing sleep problems.

Abbreviations: AOR = adjusted odds ratio, CCI = confidence interval, IPAQ = International Physical Activity Questionnaire, LTPA = leisure-time physical activity, OR = odds ratio, PA = physical activity, PSQI = Pittsburgh Sleep Quality Index, SD = standard deviation.

Keywords: firefighters, job stress, leisure-time physical activity, physical activity, sleep quality

1. Introduction
Sleep quality is directly correlated with overall health, the risk of workplace injury, and quality of life.[1,3] Both insufficient sleep and poor sleep quality have been associated with decreased working capacity.[4] The term “sleep quality” is difficult to define and differentiate from insomnia.[5] The term includes several dimensions: latency, total sleep time, number of awakenings, and sleep efficiency.[6] Previous studies have indicated that sex, education level, socioeconomic status, marital status, smoking and alcohol use, caffeine intake, and mental disorders (e.g., depression) are correlated with poor sleep quality.[5–7] It has been reported that individuals who engage in physical activity (PA) have fewer sleep disorders.[8–10] In addition, a previous study has revealed that PA could be an alternative non-pharmacological therapy for poor sleep quality.[11] The possible reasons for the improvement in sleep quality are variations in body temperature, heartbeat, mood, and concentrations of brain-derived neurotrophic factors and growth hormones.[12] However, the potential benefits of PA in improving sleep quality are under-determined because they depend on the exercise type, time spent, or intensity of PA.[1,10]
The main tasks of firefighters, including smoke ventilation, hose deployment, and lifesaving during firefighting, are considered heavy.[14] Concerning sleep disorders in this population, firefighters are a high-risk group with poor sleep quality.[15–17] A previous study on Australian wildland firefighters suggested that sleep quality was poor when firefighters lived in uncomfortable sleep conditions, had long work shifts, and had early shifts.[18] The study on Korean firefighters revealed that the frequency of insomnia was higher in firefighters with high-intensity occupational activity but had a lower risk of insomnia in firefighters partaking in leisure-time physical activity (LTPA), despite the occupational activity.[16] This result suggests that PA positively affects firefighters’ sleep quality. It is essential to emphasize how biological activity influences sleep quality and the positive effects of PA.[9] Thus, exploring the relationship between PA programs and insomnia in firefighters is necessary. This study aimed to investigate the frequency and risk factors of poor sleep quality in firefighters in Taiwan and provide appropriate recommendations to improve sleep quality.

2. Materials and methods

2.1. Study subjects

In Taiwan, firefighters are the government employees. Because they are considered to have a higher workload on duty or personal health conditions, they can self-select retirement at 50 years old or compulsory retirement at 59 years old compared to other government employees aged 65 years of retirement age. During the working period, all firefighters participated in assigned work. From November 2019 to August 2020, all firefighters (1000 persons) in the Fire Bureau, Kaohsiung City, Taiwan, were invited to participate in the study. The inclusion criteria were firefighters in the Fire Bureau of Kaohsiung City, Taiwan and complete information and questionnaires (e.g., age, sex, and history of PA). The exclusion criteria were firefighters in the Fire Bureau, Kaohsiung City, Taiwan and incomplete information and questionnaires. This study was approved by the Institutional Review Board of the Show Chwan Memorial Hospital, Taiwan (No. 1101204). Before the commencement of this study, its aim was interpreted, and it was emphasized that all data would be anonymously processed and used only for policymaking and research on the firefighting activity system. After signing the informed consent form, participants were given a structured, self-administered questionnaire addressing their relevant sociodemographic information. The questionnaire data and related results were analyzed anonymously, and any identifying information was kept confidential.

2.2. Measurements

The structured questionnaire included questions on sociodemographic characteristics including age (years), sex (male/female), marital status (married/single), type of work (office work/fieldwork [suppression fire/emergency medical service, rescue/others]), length of service for firefighters (≤5 or >5 years), work schedule (fixed shift/on-call shift), weekly regular LTPA (yes/no), and quality of sleep. The International Physical Activity Questionnaire-Short Form was used to evaluate LTPA. The Chinese version of the Pittsburgh Sleep Quality Index (PSQI) was used to measure sleep quality.

2.2.1. Leisure-time physical activity (LTPA). LTPA is defined as PA during off-duty hours.[19,20] The LTPA of the firefighters was calculated during the same study period. Taiwan firefighters adopt a fixed schedule of 24-hour work, followed by 2-days of off time. An on-call shift is a tentative schedule: workers must shift to firefighter roles at any time during a call. The work schedules of firefighters are assigned according to mission orientation, and office-based employees are also required on-call. Office-based work includes inspecting firefighting equipment or providing on-site support when there is workforce shortage or large-scale fires. Therefore, monitoring four 24-hour working days and the LTPA of each firefighter in this study required 2 weeks.

The LTPA of the previous off-duty days of each firefighter was evaluated using the Chinese form of a short form of the International Physical Activity Questionnaire (IPAQ).[21,22] The IPAQ has been translated into Chinese with adequate reliability and validity.[23] IPAQ data were transformed into metabolic equivalent (MET) scores (MET/min/week) for each activity. The MET score weighs each activity category by energy expenditure using 1 MET for sitting, 3.3 METs for working, 4 METs for moderate exercise, and 8 METs for vigorous exercise (www.acefitness.org). The sum of minutes walked and the moderate and vigorous MET scores per week provided a combined total PA score, classifying LTPA into 3 categories (low, middle, and high).

LTPA was evaluated[24] by the following question with the answer yes or no: “Do you exercise in your leisure time to strengthen your physical fitness currently?” Only participants who responded yes were further questioned about LTPA category, LTPA intensity, and resting time after LTPA. The various kinds of LTPA comprised “aerobic,” “anaerobic,” or “both,” and the participants’ answer was divided into those who were “not performing aerobic PA (anaerobic only, reference)” or those who perform “aerobic PA (aerobic only and both).” The participants were then asked, “how many times do they partake in LTPA a week and how many minutes does the LTPA last per session.” They were also requested to indicate the intensity level of their PA, including high, medium, and low. The intensity level of PA was mentioned in the questionnaire; high intensity means that PA leads to out-of-breath or increased heartbeat, and medium intensity means that PA causes mild out-of-breath or mildly increased heartbeat. We reevaluated LTPA intensity by combining the frequency and duration of each episode and the power of PA provided by the participants.

In this study, we used the Physical Activity Guidelines for Americans to develop the criteria for LTPA intensity.[23] High LTPA intensity was defined as participants who spent at least 5 times per week performing a 30-minute medium-intensity PA per episode, or those who consumed 3 times a week doing a 30-minute-high-intensity PA. Sufficient resting time after LTPA was assessed using the question (yes or no): “Are you taking enough resting time to recover after LTPA?” If the answer was yes, we classified the participants as having sufficient rest time after LTPA; otherwise, we classified them as a group that did not have enough rest time after LTPA.

2.2.2. Subjective sleep quantity and quality. The Chinese version of the PSQI was used to evaluate the subjective sleep quantity and quality of firefighters during the previous month. PSQI is a self-administered questionnaire.[24] This scale consists of 19 self-rated questions that reflect the major elements. Each was scored on a 0 to 3 scale: subjective sleep quality; sleep latency; sleep duration; habitual sleep efficiency; sleep disturbance; use of sleeping medications; and daytime dysfunction. The global PSQI score was calculated as the sum of the 7 components (ranging from 0 to 21). A lower score indicates better sleep quality, and it has been suggested that a score of <5 denotes “good” sleep quality, while ≥5 denotes “poor” sleep quality.[24] The reliability of the questionnaire used in this study was satisfactory (Cronbach’s α = 0.8).

2.3. Statistical analysis

Categorical data are presented as numbers and percentages. Continuous data are presented as mean ± standard deviation (SD). In the univariate analysis, we used the chi-square test or Fisher’s exact test for categorical variables and the t test for continuous variables to compare the risk differences between variables. In multiple logistic analysis, all variables with a P
worked on-call shift work, and approximately 79% reported >5-year experience in firefighting work; 23% of participants were <40 years of age; >90% of participants were responsible for fieldwork (fire suppression, emergency medical service [EMS], rescue, and others); >80% of participants had >5-year experience in firefighting work; 23% of participants worked on-call shift work, and approximately 79% reported having regular weekly LTPA. A total of 447 (50.3%) participants reported poor sleep quality (Table 1).

Figure 1 shows the PSQI scores distribution among the study subjects. The mean PSQI score of the study subjects was 6.13 (SD ± 2.69). The highest frequency of PSQI was 5, followed by 4 and 6.

Table 1 shows the univariate analysis of poor and good sleepers among the firefighters. Compared to good sleepers, female participants who had more firefighting work experience (>5 years), were on on-call shift work, and did not participate in regular weekly LTPA were more likely to be poor sleepers (all P < .05). Age, marital status, and job type were not related to the risk of poor sleep (all P > .05). Compared with participants with good sleep, those with poor sleep had significant differences in the components of the PSQI subgroup score, including subjective sleep quality (P < .001), sleep latency (P < .001), sleep duration (P < .001), habitual sleep efficiency (P = .03), sleep disturbance (P < .001), use of sleep medication (P < .001), and daytime dysfunction (P < .001).

Table 2 shows the results of the multiple logistic regression analysis. The AOR for poor sleep quality was calculated for age, sex, firefighter service length, work schedule, and LTPA participation. The following risk factors were found to be significant predictors of poor sleep among firefighters: female sex (AOR = 7.65, 95%CI: 3.29–18.70, P < .001), longer work duration (>5 years) for firefighters (AOR = 2.50, 95%CI: 1.73–3.02, P < .001), on-call shift work schedule (AOR = 2.11, 95%CI: 1.52–2.92, P < .001), and no regular weekly partaking LTPA (AOR = 0.50, 95%CI: 0.33–0.64, P = .002). There was no association between the risk of poor sleep and age (P > .05).

### Table 1

Univariate analysis between the poor and good sleepers among firefighters in Taiwan.

| Variables                              | Total N = 889 | Poor Sleepers N = 447 | Good Sleeper N = 442 | P value     |
|----------------------------------------|---------------|-----------------------|----------------------|-------------|
| Age (mean ± SD)                        | 38.92 ± 8.36  | 39.04 ± 8.42          | 38.13 ± 7.33         | .097        |
| Gender                                 |               |                       |                      | <.001       |
| Male                                   | 833 (93.7)    | 398 (47.8)            | 435 (52.2)           |             |
| Female                                 | 56 (6.3)      | 49 (57.5)             | 7 (12.5)             |             |
| Marital status                         |               |                       |                      | .368        |
| Single                                 | 431 (48.5)    | 210 (48.7)            | 221 (51.3)           |             |
| Married                                | 458 (51.5)    | 237 (51.7)            | 221 (48.3)           |             |
| Age groups (yr)                        |               |                       |                      | .194        |
| ≤40                                    | 478 (53.8)    | 250 (52.3)            | 228 (47.7)           |             |
| >40                                    | 411 (46.2)    | 197 (47.9)            | 214 (52.1)           |             |
| Types of job                           |               |                       |                      | .690        |
| Office work                            | 86 (9.7)      | 45 (52.3)             | 41 (47.7)            |             |
| Fieldwork                              | 803 (90.3)    | 402 (50.1)            | 401 (49.9)           |             |
| Length of service for firefighter (yr) |               |                       |                      | <.001       |
| ≤5                                     | 153 (17.2)    | 49 (32.0)             | 104 (68.0)           |             |
| >5                                     | 736 (80.8)    | 398 (54.1)            | 338 (45.9)           |             |
| Work schedule                          |               |                       |                      | <.001       |
| Fixed shift                            | 687 (77.3)    | 317 (46.1)            | 370 (53.9)           |             |
| On-call shift                          | 202 (22.7)    | 130 (64.4)            | 72 (35.6)            |             |
| Regular partaking LTPA weekly          |               |                       |                      | .007        |
| No                                     | 190 (21.4)    | 112 (58.9)            | 78 (41.1)            |             |
| Yes                                    | 699 (78.6)    | 335 (47.9)            | 364 (52.1)           |             |
| PSQI total (mean ± SD)                 | 6.13 ± 2.69   | 8.26 ± 2.07           | 3.98 ± 0.98          | <.001       |
| Subjective sleep quality (C1)          | 0.93 ± 0.95   | 1.09 ± 0.92           | 0.78 ± 0.60          | <.001       |
| Sleep latency (C2)                     | 1.13 ± 0.63   | 1.32 ± 0.62           | 0.93 ± 0.57          | <.001       |
| Sleep duration (C3)                    | 0.96 ± 0.78   | 1.10 ± 0.79           | 0.81 ± 0.74          | <.001       |
| Habitual sleep efficiency (C4)         | 0.51 ± 0.73   | 0.55 ± 0.78           | 0.40 ± 0.71          | .030        |
| Sleep disturbance (C5)                 | 1.39 ± 0.53   | 1.65 ± 0.54           | 1.13 ± 0.38          |             |
| Use of sleep medication (C6)           | 0.22 ± 0.62   | 0.30 ± 0.64           | 0.18 ± 0.47          | <.001       |
| Daytime dysfunction (component 7)      | 0.99 ± 0.83   | 1.46 ± 0.76           | 0.52 ± 0.60          | <.001       |

EMS = emergency medical service, LTPA = leisure-time physical activity, PSQI = Pittsburgh Sleep Quality index, SD = standard deviation.

* Filed work: suppression of fire/emergency medical service/rescue/others.

3
We performed an advanced analysis of the relationship between the characteristics of patients with LTPA and their sleep quality. Table 3 shows the association between the characteristics of the patients with LTPA and sleep quality. The adjusted OR was calculated for age, sex, years of firefighting work, and work schedule. Among the characteristics of those who participated in LTPA, those who participated in high-intensity LTPA (AOR = 2.18, 95% CI: 1.51–3.14, \( P < .001 \)) were positively associated with the risk of poor sleep, whereas those who had sufficient rest after LTPA (AOR = 0.44, 95% CI: 0.27–0.72, \( P < .001 \)) were significantly negatively associated with the risk of poor sleep. LTPA type was not significantly associated with poor sleep (\( P > .05 \)).

4. Discussion

Most previous studies have been performed on the general population, whereas this study was conducted on target firefighters. This is the first study to evaluate the prevalence of poor sleep quality and its related risk factors in firefighters in Taiwan. The prevalence of poor sleep quality among the firefighters in this study was approximately 50.3%. Compared with a previous study, our study found that the prevalence of poor sleep quality among firefighters (50.3%) was consistent with the results of an earlier study in Thailand (49.1%).

A previous study has revealed that poor sleep quality is directly related to age and sex. Previous studies have indicated that sex moderates the effects of acute exercise on some aspects of sleep. However, these studies did not provide sufficient evidence of sex moderation between regular PA and sleep quality or duration. A previous study indicated that walking in older people with sleep disorders was correlated with improved sleep quality in women, but not in men. Regarding other gender differences in health behaviors, psychological disorders, such as anxiety and depression, commonly affect sleep quality in women, which could be recognized as the factors contributing to gender differences in the general population. However, hormonal variations after puberty have been proposed as predictors of sex differences in sleep quality in adults. Some studies have shown that women are more sensitive to their internal body states. In the study of Zeng et al. indicated gender factors were significantly associated with the differences between domain-specific physical activities and poor sleep quality. This may be due to complex interactions between gender characteristics and the construct of the PA domain. Our results are consistent with those of the previous studies. However, our findings should be interpreted with caution, as our study population comprised 94% of men, and the results may have changed if more women were enrolled.

Several studies have investigated the workloads of firefighters performing office work and firefighters working in the field, including fire suppression, EMS, and rescue. It may be due to the reason that work stress is a potential factor influencing the physical strength of workers. However, several studies have examined workloads among office workers, and have shown that office work is moderate to vigorous. Firefighters who work in offices face physical or mental stress, including inspection of firefighting equipment or provision of on-site support, when there is a workforce shortage or large fires. A previous study showed that approximately 24% of male firefighters and 20% of female firefighters engaged in office work reported experiencing heavy physical and mental stress. This means that firefighters working in offices are also exposed to significant job stress, not less job loading than firefighters who work in the field. Consistent with a previous study, our study found no significant differences in sleep quality between firefighters engaged in office work and those who worked in the field.

Firefighters rescue and provide first aid to humans in distress during emergencies. They encounter many stressful situations such as heat, chemical, biological, physical, and mental stress. The mechanism of job stress-induced sleep disorders may be caused by the activation of the hypothalamic-pituitary-adrenal axis and autonomic nervous system, which leads to arousal and sleeplessness in animals and humans. Thus,
Firefighting is considered a high-risk task. It has been reported that high job stress or a high loading of occupational activity is significantly related to poor sleep quality.\[^{3,5,38}\] Also, firefighters with poor sleep quality are at significantly increased risk when they feel much of a physical burden during firefighting.\[^{34}\] Our study found that firefighters with more years of work experience were at higher risk of poor sleep quality. This may be due to more years of firefighting work, resulting in more job stress.

Shift work is associated with overall health and sleep disorders that may lead to cognitive impairment.\[^{19,40}\] Shift work is not only a high workload but also causes poor sleep quality by disrupting the circadian rhythm.\[^{36,40}\] It also has been found that increased physical and psychological stress leads to the enhanced synthesis of endocrine hormones.\[^{41}\] This appears to be more stressful for a 24-hour-on-call shift for firefighters. Extended on-duty changes result in acute and chronic poor sleep and circadian disruptions.\[^{31,42}\] The type of shift work (fast and slow shift rotation) is still controversial, which is preferable for workers’ health.\[^{39}\] It has been reported that fixed shifts might improve workers’ health and sleep compared with unstable shifts.\[^{43}\] However, the uncertainty of the call schedule can produce significant stress for workers; for example, workers are required to change their home life or face various events to adjust to their firefighter roles at any time during the call.\[^{43}\] These dilemmas present unique challenges for on-call workers that are not met by those working fixed shift schedules or even firefighters with rotating shifts.\[^{44}\] Repeated stress responses can affect physical and mental health.\[^{37}\] Consistent with previous studies,\[^{41,42}\] our study showed that poor sleep quality was higher in firefighters with on-call scheduled jobs than in those with fixed shift work schedules. This is a significant health issue among on-call shift workers.

Regular PA is recognized as a protective factor for health and well-being.\[^{45,46}\] PA can improve the central circadian pacemaker and serve as an external stimulus to strengthen the sleep-wake pattern.\[^{46,47}\] LTPA may reduce nonrestorative sleep (NRS) in workers with jobs with extreme physical demands.\[^{48}\] A previous study showed that LTPA conferred a significantly positive association between the cardiovascular workload and firefighters.\[^{49}\] Consistent with previous studies,\[^{20,45}\] our study found a positive relationship between LTPA and sleep quality.

We also investigated the association between the LTPA intensity and sleep quality. In this study, high-intensity LTPA was defined as ≥5 episodes per week and ≥30 minute per episode of moderate-intensity PA (activity that leads to slight out-of-breath or slightly increased heartbeat) or ≥3 episodes per week and ≥30 minute per episode of high-intensity PA (activity that leads to severe out-of-breath or increased heartbeat). According to the Biological Activity Guidelines for American Adults,\[^{50}\] this definition has been used in a study on exercise among Korean firefighters.\[^{49}\] Although this classification method for LTPA intensity has been used in other studies, it is necessary to evaluate actual LTPA intensity by calculating the metabolic equivalent in future studies. It has been reported that high-intensity LTPA significantly decreased the risk of poor sleep quality.\[^{50}\] However, these studies only considered the effects of LTPA, and did not include occupational activity on poor sleep quality. Additionally, there is insufficient evidence to explain the impact of high-intensity interval training on sleep quality indicators.\[^{51}\] Firefighters have already encountered high job stress because they must engage in high-intensity occupational activities even during off-duty days.\[^{48}\] Therefore, intervention measures to improve the sleep quality of firefighters differ from those used in the general population.

According to previous research,\[^{46}\] resting time after LTPA is a factor that affects sleep quality. Additionally, previous studies have indicated that high-intensity LTPA within a few hours of bedtime can negatively affect sleep quality.\[^{10,11}\] Furthermore, the effect of LTPA on poor sleep quality during the day remains controversial.\[^{11}\] Still, it has also been found that partaking in LTPA late in the evening can influence melatonin secretion, slow the circadian rhythm, and lead to sleep disorders.\[^{52}\] Resting time after LTPA is also an essential factor affecting sleep quality. The attenuated responses of oxidative stress, antioxidant capacity, and decreased serotonin reuptake in the brain to overtrained exercise may be related to the inability to perform exercise effectively and impaired adaptation to exercise.\[^{13,54}\] However, the exact mechanisms underlying this overtraining remain unclear. In the future, more research on the effects of these factors on poor sleep quality is required.

Our study had several limitations. First, this was a cross-sectional study, and we could not verify the causal relationship between the investigated risk factors and severity of poor sleep quality. Second, we did not consider interactions between poor sleep and depression, anxiety, or post-traumatic stress disorder symptoms. However, there is a bidirectional correlation between poor sleep quality and mental health disorders.\[^{53}\] Therefore, clarifying the effects of PA-related characteristics on sleep quality risk is necessary. Third, since the study’s primary outcome, poor sleep quality, was assessed using a self-report questionnaire, non-response and recall biases cannot be excluded. A sleep and PA survey identified sleep indicators, including total sleep time, rapid eye movement sleep time, and sleep onset latency through polysomnography,\[^{55}\] but the present study did not. In the future, it will be necessary to study the relationship between objective sleep quality and LTPA in firefighters. Fourth, although this study showed that sufficient resting time after LTPA is an essential factor influencing sleep quality, there are no clear criteria for sufficient resting time. The results of the present study were subjective. Further studies concerning the measures of sufficient resting time after LTPA and the duration of rest after LTPA are needed.

5. Conclusions

This study found that the prevalence and risk of poor sleep quality are higher among firefighters in Taiwan. Additionally, the risk of poor sleep quality was significantly lower in participants who were taking LTPA and those who had sufficient resting time after LTPA. Additionally, participants who performed high-intensity LTPA had a substantially higher risk of poor sleep quality than those who performed low-intensity LTPA. Therefore, considering firefighters’ work characteristics, regular LTPA should be encouraged to improve sleep quality. However, exercise programs should be planned and recommended to provide sufficient rest after exercise.

Author contributions

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