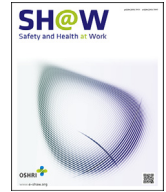




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## Original Article

## Sleep Assessment During Shift Work in Korean Firefighters: A Cross-Sectional Study

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## ABSTRACT

**Background:** This cross-sectional study assessed the sleep quality using the ActiGraph and investigated the relationship between the parameters of sleep assessment and the type of shift work in Korean firefighters.

**Methods:** The participants were 359 firefighters: 65 day workers (control group) and 294 shift workers (shift work group: 77 firefighters with 3-day shift, 72 firefighters with 6-day shift, 65 firefighters with 9-day shift, and 80 firefighters with 21-day shift). Sleep assessments were performed using the ActiGraph (wGT3X-BT) for 24 hours during day shift (control and shift work group) and night shift and rest day (shift work group). The participants recorded bed time and sleep hours during the measurement period.

**Results:** Sleep efficiency, total sleep time, and percentage of wake after sleep onset during night work were lower in the shift work group than control group ( $p < 0.05$ ). Sleep efficiency decreased in night shift and increased in rest day, whereas wake after sleep onset increased in night shift and decreased in rest day ( $p < 0.05$ ). Among shift work groups, sleep efficiency of 6-day shift was higher in day shift, and sleep efficiency of 21-day shift was lower in night shift than other shift groups ( $p < 0.05$ ).

**Conclusion:** We found that the sleep quality in night shift of the shift work group was poorer than the control group. As to the type of shift work, sleep quality was good in 6-day shift and poor in 21-day shift. Thus, fast rotating shift such as 6-day shift may be recommended to improve the sleep quality of the firefighters.

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### 1. Introduction

Shift work means a work schedule in which a worker replaces another on the same job within a 24-hour period [1]. However, this is a narrow definition, and another definition of shift work is work that extends beyond the typical “nine-to-five” workday or work outside of the hours from 06:00 a.m. to 08:00 p.m [2,3]. There are many types of shift work with respect to the structure: the presence or absence of night work, the duration of the shift (6 hours, 8 hours, 12 hours, or 24 hours), the number of workers or teams (two, three, four, or more teams), the change of working time (permanent or

rotating), and so on [4]. Shift work is commonly used not only in manufacturing industry to increase productivity but also in the hospital, police stations, and fire departments for public interest.

The term “circadian” is derived from the Latin phrase “circa diem.” “Circa” means “about” or “approximately,” and “diem” means “day.” Therefore, circadian rhythm refers to a physiological process that changes over a period of approximately 24 hours, after which it repeats itself [5,6]. In humans, the circadian rhythm is controlled by a biochemical oscillator called the circadian clock, which is located in the suprachiasmatic nuclei in the hypothalamus [7,8]. The strongest factor that changes the circadian rhythm is the

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	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
day	D	D	D	D	D	R	R	D	D	D	D	D	R	R	D	D	D	D	D	R	R
3-d	24	R	R	24	R	R	24	R	R	24	R	R	24	R	R	24	R	R	24	R	R
6-d	D	D	N	N	R	R	D	D	N	N	R	R	D	D	N	N	R	R	D	D	N
9-d	D	D	D	N	R	N	R	N	R	D	D	N	R	N	R	N	R	N	R	D	D
21-d	D	D	D	D	D	R	R	N	R	N	R	N	R	24	R	N	R	N	R	24	R

**Fig. 1.** Type of shift work in Korean firefighters. The number (1–21) means the date, and gray scale means the measurement day. 3-d, 3-day shift; 6-d, 6-day shift; 9-d, 9-day shift; 21-d, 21-day shift; 24, 24-hour shift; day, day work; D, day work group; R, rest day; N, night shift.

light [9]. Thus, if external time changes (such as when an individual travels by an airplane to a different time zone), the circadian clock is reset so that it synchronizes with the external time.

Shift workers work at different times from normal workers. As a result, shift workers must adopt sleep–wake patterns that can differ radically from the sleep–wake patterns of normal workers. This is particularly true for night shift workers. These changes in the sleep–wake patterns alter the circadian rhythms of shift workers and induce various health hazards including sleep disorder [3,10], cardiovascular disorder [11], gastrointestinal disorder [12], mental illness [13], breast cancer [14,15], and so on.

Firefighters must remain on duty 24 hours a day for public safety. Unlike other shift workers, however, firefighters are able to sleep during their night work if an emergency or fire does not occur. Thus, their bed time and sleeping hours vary greatly depending on the situation of their night work. In the previous research studies, firefighters have been reported to experience sleep deprivation or poor sleep quality [16–19]. Most of them investigated sleep problems with a questionnaire using the Pittsburgh Sleep Quality Index (PSQI) [16,19], Epworth Sleepiness Scale [16], or Berlin Questionnaire [18]. There were few studies that had evaluated the sleep quality with objective methods. Some researchers evaluated the sleep quality with objective methods, but the number of participants was not large. We designed a cross-sectional study to conduct the sleep assessment using the ActiGraph and investigated the relationship between the parameters of sleep assessment and the type of shift work in Korean firefighters.

## 2. Participants and methods

### 2.1. Study design and ethics

This study had a cross-sectional study design and was approved by the Institutional Review Board of Dongguk University Ilsan Hospital (DUIH 2017-08-014-001). The study was conducted according to the tenets of the Declaration of Helsinki and its revisions. All participants consented in writing to participate in the study after being informed of the nature of the study and its benefits and potential risks.

### 2.2. Participants

Overall, Korean firefighters work several types of shift work, namely, a 3-day, a 6-day, a 9-day, or a 21-day shift schedule. The 3-day shift consists of one 24-hour shift, followed by two rest days. The 6-day shift consists of two day shifts (9:00 a.m. to 6:00 p.m.), followed by two 12-hour night shifts (6:00 p.m. to 9:00 a.m.) and two rest days. The 9-day shift consists of three day shifts, followed by three 12-hour night shifts; each night shift is succeeded by one rest day. In the 21-day shift, the first week consists of 5 days of day

shifts, followed by 2 days of rest. The second week consists of 12-hour night shifts alternating with a rest day until Day 14, which is a 24-hour shift. The third week starts with a rest day, followed by two 12-hour night shifts interspersed with rest days. On Day 20, the firefighter works a 24-hour shift. The last day is a rest day (Fig. 1). The participants of the present study consisted of two groups, namely, firefighters who performed shift work (shift work group) and firefighters who only worked during the day (control group). The participants in both groups were selected from 11 fire stations in South Korea. These stations were selected to ensure that all types of shift workers were included. The study took place between October 2017 and April 2018.

To improve the representativeness of the study participants, they were selected using a stratified random sampling method. The firefighters were then stratified according to gender, age (<40, 40–49, and  $\geq 50$  years), and type of shift work (day or shift work). The statements of PROC SURVEY, PROC SORT, and PROC RANK in SAS Windows version 9.4 (SAS Institute Inc., Cary, NC, USA) were used to generate random numbers and determine the priority of the firefighters in each stratified group. If the participant selected as first priority was unable to participate, the participant selected as second priority was chosen instead. Participants who were transferred to another department or absent because of sick leave during the study period and participants who failed to complete the sleep assessment were excluded.

In total, 433 firefighters were randomly selected from 11 fire stations. Seventy participants were excluded: transferred to another department ( $n = 3$ ), absent due to sick leave during the study period ( $n = 1$ ), and failed to complete the sleep assessment ( $n = 66$ ). The final study cohort consisted of 363 firefighters; of whom, 65 were day workers (control group) and 298 were shift workers (shift work group). The shift work group included 77 firefighters with 3-day shift, 72 firefighters with 6-day shift, 67 firefighters with 9-day shift, and 82 firefighters with 21-day shift.

### 2.3. Measurements

The ActiGraph (wGT3X-BT; ActiGraph, 49 E, Chase St, Pensacola, FL 32502, USA) was reported to provide a satisfactory objective measurement of sleep quality [20]. We used the ActiGraph for sleep assessment of the participants. The ActiGraph was worn in the nondominant wrist of each participant. The participants were requested to wear the ActiGraph properly and not to remove it except when entering water (such as when showering or swimming). All participants were also informed about how to wear the ActiGraph after removing them. In addition, the participants were requested to refrain from vigorous exercise and alcohol drinking on the day before and the day of each measurement.

Measurements were conducted over 1 day in the control group and 2 or 3 days in the shift work group. The measurements were

**Table 1**  
Demographic and work-related characteristics of the study participants.

Variables	Control group (n = 65)	Shift work group (n = 294)	p-value
Age, years			
< 40	23 (35.4)	153 (52.0)	0.0429
40–49	26 (40.0)	94 (32.0)	
≥ 50	16 (24.6)	47 (16.0)	
Sex			
Male	54 (83.1)	269 (91.5)	0.0408
Female	11 (16.9)	25 (8.5)	
Body mass index, kg/m <sup>2</sup>			
< 25	43 (66.2)	196 (66.7)	0.9368
≥ 25	22 (33.8)	98 (33.3)	
Smoking			
Never or ex-smoker	49 (75.4)	218 (74.2)	0.8365
Current smoker	16 (24.6)	76 (25.8)	
Alcohol drinking			
No or social	12 (18.5)	66 (22.4)	0.4805
Moderate or heavy*	53 (81.5)	228 (77.5)	
Exercise			
Light <sup>†</sup>	31 (47.7)	79 (26.9)	0.0043
Moderate <sup>‡</sup>	17 (26.2)	102 (34.7)	
Vigorous <sup>§</sup>	17 (26.2)	113 (38.4)	
Job			<0.0001
Administrative	59 (90.8)	0 (0.0)	
Fire suppression	3 (4.6)	92 (31.3)	
EMS	1 (1.5)	57 (19.4)	
Rescue	0 (0.0)	52 (17.7)	
Others	2 (3.1)	93 (31.6)	
Job duration (years)			0.0226
< 10	24 (36.9)	163 (55.4)	
10–19	14 (21.5)	50 (17.0)	
≥ 20	27 (41.5)	81 (27.6)	

EMS, emergency medical service.

The data are shown as number (%), and p-value was calculated using the Chi-square test.

\* Drinks more than 7 cups of soju in a week.

<sup>†</sup> Exercise: light activity less than 1 hour in a week.

<sup>‡</sup> Exercise: light activity more than 1 hour or moderate activity less than 3 hours in a week.

<sup>§</sup> Exercise: moderate activity more than 3 hours in a week.

performed in 24-hour shift and rest day in 3-day shift, day and night shift in 6-day shift, day shift, night shift and rest day in 9-day shift, and day shift, night shift, and rest day in 21-day shift (Fig. 1). On each day, sleep assessment with the ActiGraph was performed for 24 hours. Once the measurement was completed, the data were downloaded onto the computer using ActiLife® 6 software (49 E, Chase St, Pensacola, FL 32502, USA).

A sleep diary was provided to identify sleep patterns during the measurement period. Sleep diary included the information for bed time and sleep hours. The participants were requested to record bed time and sleep hours in the sleep diary.

#### 2.4. Sleep assessment and calculation of energy consumption

We used ActiLife® 6 software for sleep assessment. The information of each participant such as age, sex, height, and weight was added when initializing the ActiGraph with ActiLife® 6. We entered the time to bed and time from bed in ActiLife® 6 software and calculated the following parameters: sleep latency, sleep efficiency, time in bed, total sleep time, and wake after sleep onset (WASO).

**Table 2**  
The results of sleep assessment of the study participants.

Parameters	Day work	Night work	Rest day
Control group			
Sleep latency, %	12.2±4.0		
Sleep efficiency, %	83.4±5.4		
Time in bed, min	413.5±67.2		
Total sleep time, min	339.7±72.4		
WASO, min	55.9±23.2		
WASO%, %	13.5±5.3		
Shift work group			
Sleep latency, %	10.8±3.8	12.6±6.9	12.7±7.0
Sleep efficiency, %	84.1±5.5	74.2±9.0 <sup>*,†</sup>	81.1±6.9 <sup>†</sup>
Time in bed, min	412.0±93.8	357.9±102.3	419.3±113.3
Total sleep time, min	347.7±87.6	266.9±84.8 <sup>*,†</sup>	341.0±100.9
WASO, min	53.5±24.8	78.3±40.6 <sup>†</sup>	65.3±32.3 <sup>†</sup>
WASO%, %	13.2±5.6	21.9±8.8 <sup>*,†</sup>	15.7±6.9 <sup>†</sup>

ANCOVA, analysis of covariance; ANOVA, analysis of variance; BMI, body mass index; WASO, wake after sleep onset.

The data are shown as mean ± standard deviation. WASO and WASO% means wake after sleep onset and the percentage of wake after sleep onset in the time in bed.

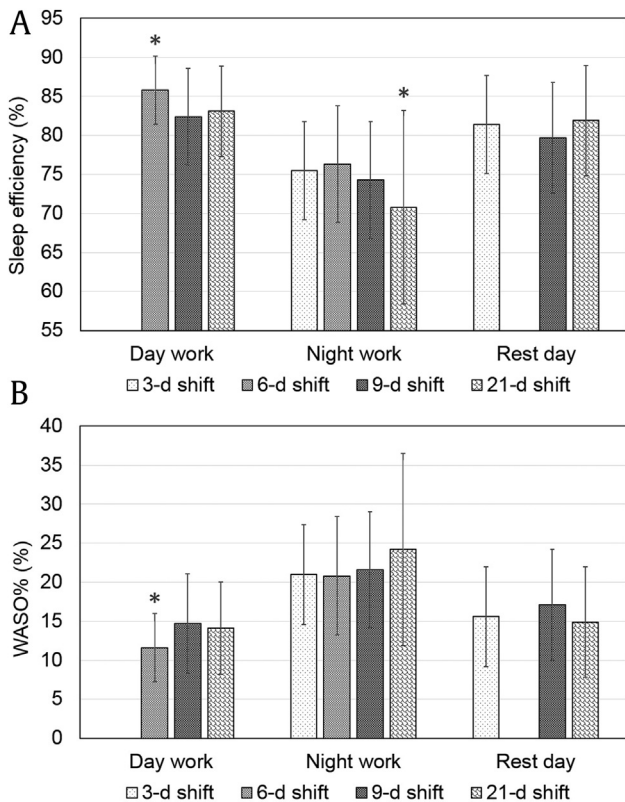
\* Significantly different compared with the control group in ANCOVA, adjusted for age, sex, BMI, smoking, alcohol drinking, exercise, job, job duration, and region of department.

<sup>†</sup> Significantly different compared with day work of the shift work group in repeated measures ANOVA, adjusted for age, sex, BMI, smoking, alcohol drinking, exercise, job, job duration, and region of department.

Sleep latency means the length of time from full wakefulness to sleep. Sleep efficiency means the ratio of the total time spent sleeping (total sleep time) compared with the total amount of time spent in bed (time in bed). WASO means the amount of time of all wake epochs between sleep onset and sleep end. WASO% means the percentage of WASO in the time in bed. Lower sleep efficiency and higher WASO represent poor sleep quality.

#### 2.5. Statistical analysis

Age was categorized into three groups (<40, 40–49, and ≥50 years). Body mass index (BMI) was categorized into two groups (<25 and ≥25 kg/m<sup>2</sup>). Smoking was categorized into two groups (never or ex-smoker and smoker). Participants who drank more than seven cups of soju per week were considered to be moderate or heavy drinkers. Exercise was categorized as light (light activity for <1 hour/week), moderate (light exercise for >1 hour/week or moderate activity for <3 hours/week), or vigorous (moderate exercise for >3 hours/week). Firefighter's job was categorized as administrative, fire suppression, emergency medical service, rescue, and others. Duration of job was categorized into three groups (<10, 10–19, and ≥20 years). The control and shift work groups were compared in terms of demographics, smoking, alcohol drinking, and exercise using Chi-square tests. The analysis of covariance (ANCOVA) test was carried out for comparing the parameters of sleep assessment between the control and shift work group. In addition, the one-way repeated measures analysis of variance test was performed for comparing the parameters of sleep assessment between day work, night work, and rest day in the shift work group. The ANCOVA test was performed to compare sleep efficiency and WASO% among 3-day, 6-day, 9-day, and 21-day shifts during measurement days, in which Scheffé's test was used for the post hoc test [21]. Age, sex, BMI, smoking, alcohol drinking, exercise, job, job duration, and region of department were adjusted in ANCOVA and one-way repeated measures analysis of variance. All statistical analyses were performed using SAS windows



**Fig. 2.** Distribution of (A) sleep efficiency and (B) WASO% (percentage of wake after sleep onset) of the shift work group. The bar represents the standard deviation of sleep efficiency and WASO%. The 3-day shift does not contain day work, so there are no available data of day work in the 3-day shift. Sleep assessment was not performed in the rest day of the 6-day shift. \*Significantly different compared with other shift patterns, adjusted for age, sex, BMI, smoking, alcohol drinking, exercise, job, job duration, and region of department. 3-d, 3-day shift; 6-d, 6-day shift; 9-d, 9-day shift; 21-d, 21-day shift.

version 9.4 (SAS Institute Inc.). The  $p$ -values of  $<0.05$  were considered to indicate statistically significant differences.

### 3. Results

Table 1 shows the demographic and work-related characteristics of the control and shift work groups. The age and sex distributions were significantly different between the two groups ( $p < 0.05$ ). The shift work group had younger participants and had more men than the control group. The two groups did not differ significantly in terms of BMI, smoking status, or alcohol drinking. In terms of exercise, the shift work group had more moderate or vigorous exercise than the control group ( $p < 0.05$ ). The job of most control group participants was administrative (90.8%), whereas there is no administrative job in the shift work group. The job duration was longer in the control group than the shift work group ( $p < 0.05$ ). The demographic and work-related characteristics of 3-day shift, 6-day shift, 9-day shift, and 21-day shift are shown in Supplement Table 1.

Table 2 shows the results of the sleep assessment of the control and shift work group. All parameters were not significantly different between two groups during day work. In the shift work group, sleep efficiency in night work significantly decreased in day work and increased in rest day ( $p < 0.05$ ), whereas WASO and WASO% in night work significantly increased in day work and decreased in rest day ( $p < 0.05$ ). Sleep efficiency, total sleep time, and WASO% in night work of the shift work group were significantly different from those of the control group ( $p < 0.05$ ), but all

parameters in rest day of the shift work group were not significantly different from those of the control group. The prevalence of low sleep efficiency (less than 85%) was 36 (55.4%) in the control group and 214 (72.8%), 273 (92.9%), and 230 (78.2%) in day work, night work, and rest day of the shift work group, respectively. The results for sleep assessment of 3-day shift, 6-day shift, 9-day shift, and 21-day shift are shown in the Supplement Table 2.

Fig. 2 is the distribution of sleep efficiency and WASO% of the shift work group, which shows that sleep efficiency decreased in night work and increased in rest day, whereas WASO% increased in night work and decreased in rest day. In day work, sleep efficiency of the 6-day shift was significantly higher and WASO% of 6-day shift was significantly lower than those of other shift groups ( $p < 0.05$ ). In night work, sleep efficiency of the 21-day shift was significantly lower than that of other shift groups ( $p < 0.05$ ). There was no significant difference in terms of sleep efficiency and WASO% in rest day.

### 4. Discussion

In the present study, we found that sleep quality in night work and rest day of the shift work group was poorer than that in the control group. Among shift work groups, sleep efficiency in day work of the 6-day shift was higher than that in other groups, and sleep efficiency in night work of the 21-day shift was lower than that in other groups.

Sleep disturbances are reported to be prevalent in firefighters in the previous research studies. Barger et al. [18] used self-report screening tools including the Berlin Questionnaire, Athens Insomnia Scale, Restless Legs Syndrome Epidemiology, and Symptoms and Treatment Questionnaire and reported that 37.2% of firefighters have sleep disorders including obstructive sleep apnea, insomnia, shift work disorder, and restless leg syndrome. Billings and Focht [19] used the PSQI and reported that 73% of firefighters had reported poor sleep quality. Haddock et al. [22] used the Epworth Sleepiness Scale and reported that the prevalence of excessive daytime sleepiness was 13.7–14.0%, which was related with 48-hour work shifts. Yun et al. [23] used the General Health Questionnaire and reported that 51.2% reported sleep disturbances. Lim et al. [24] used the PSQI and reported that the prevalence of sleep disorders was 48.7%, which was associated with shift work. As aforementioned research studies, the prevalence varied depending on the measurement method for sleep disturbances. In the present study, the prevalence of low sleep efficiency (less than 85%) was 55.4% in the control group and 72.8%, 92.9%, and 78.2% in day work, night work, and rest day of the shift work group, respectively.

There were not many research studies that investigated the sleep quality of firefighters using the ActiGraph. Vincent et al. [25] assessed the sleep quantity and quality of planned burn operation (the burning of the fire-prone areas to reduce the rate of spread, intensity, and resultant size of future wildfires). They observed no differences in sleep quantity and quality between nonburn and burn days, but total sleep time was less in long-length ( $>12$  hours) shifts. Vincent et al. [26] examined firefighters' sleep quantity and quality throughout multiday wildfire suppression. Sleep quantity (time in bed and total sleep time) was significantly lower during fire days than nonfire days, but sleep quality (sleep efficiency) was not significantly different. They found that sleep location, shift length, and shift start time were associated with total sleep time and suggested that modifying the characteristics of work shifts and the sleeping environment could improve sleep quantity. McGillis et al. [27] assessed the sleep quality of Canadian wildland firefighters using the ActiGraph. They reported that the sleep efficiency was 75.6% during initial attack (the actions taken by the firefighters to prevent lives and property and prevent further extensions of the fire), which



was significantly lower than that of base work (85.7%). The total sleep time and WASO during initial attack were  $287.2 \pm 69.3$  and  $92.8 \pm 82.8$  minutes, respectively, which were also significantly different compared with those of base work ( $371.6 \pm 58.1$  and  $58.8 \pm 33.9$  minutes, respectively). Among the aforementioned research studies, only one research showed that sleep quality was lower during fire suppression (initial attack), although sleep quantity was lower in all research studies. However, in the present study, both sleep quantity (time in bed and total sleep time) and quality (sleep efficiency) during night work was significantly lower compared with the control group and day work of the shift work group. The participants in the aforementioned research studies did not perform night work, whereas we included both day and shift work groups. For this reason, both sleep quantity and quality during night work was significantly low in the present study, unlike the previous research studies.

In the present study, sleep quality of 6-day shifts was better in day work than other types of shift work (higher sleep efficiency and lower WASO%). In the night shift, sleep quality of 21-day shifts was poorer than that of other types of shift work (lower WASO%). This finding may be resulted from the duration of night shifts. The night shift duration of the 6-day shift was 2 days, which was shorter than 14 days of the 21-day shift. For this reason, sleep quality was found to be better in the 6-day shift than 21-day shift. The night shift duration of the 3-day shift was also short as the 6-day shift, but the comparison of sleep quality in day work was not performed because the 3-day shift did not include day work. As to rotating shift work, there are fast rotating (changing shift every 2 or 3 days) and slow rotating shifts (changing shift every 3 or 4 weeks), according to speed of rotation. There has been controversy between researchers about which type of shift work is better between fast and slow rotation. The fast rotating shift has the advantage that minimizes continuous night shifts, which induce sleep loss and fatigue, and allows workers to spend more time with their family. For this reason, some researchers recommended fast rotating shifts rather than slow rotating shifts [28–30]. Whereas, slow rotating shifts allow workers enough time to adopt night shifts. Some researchers reported that sleep quality and well-being of slow rotating shifts was better than those of fast rotating shifts and recommended slow rotation rather than fast rotation [31–33]. Although there is disagreement about fast and slow rotation, most researchers recommended weekly rotating shifts should be avoided whenever possible [34]. Weekly rotating shifts allow the workers' circadian rhythm to adjust to external time, but their circadian rhythm should readjust when they change their shift. Thus, their circadian rhythm fluctuates during both their day and night shifts, which induces circadian disruption. Among the types of shift work in the participants of the present study, 3-day and 6-day shifts are fast rotating shifts because one shift is one day (3-day shift) and 2 days (6-day shift). As to 9-day and 21-day shifts, firefighters should perform night shift every other day during 6 and 14 days, respectively. Although it is not successive, night shifts, both 9-day and 21-day shift, are different from fast rotating or slow rotating shifts. The findings of the present study that sleep quality of 6-day shifts was good and that of 21-day shifts was poor support the previous research studies that the fast rotating shift was better [28–30], whereas the present study does not show that the slow rotating shift is not good because slow rotating shifts that change 3 or 4 weeks were not included in the present study.

The present study has several limitations. First, we did not assess how often the night sleep of the firefighters in night work was disrupted by the need to attend to emergencies. The frequency of emergencies in night work may be associated with the sleep quality. Second, we did not evaluate the psychological conditions such as anxiety and depression, which is known to be associated with sleep disturbances [35]. Third, the information about the detailed job history of each participant was not obtained. Thus, we

could not adjust the duration of job history in the statistical analyses. Fourth, we did not evaluate the sleep quality for the whole day in each shift work. Thus, future study is needed to perform sleep assessment for longer duration in each shift work.

This is the first study that evaluated the sleep quality using the objective measurement, the ActiGraph, in the firefighters engaged with shift work including night work. According to the findings of the present study, the 6-day shift, which was better than other shift schedules, may be recommended to improve the sleep quality of the firefighters. The findings of the present study may be helpful to design the shift work for the firefighters. Further studies are needed to investigate the sleep quality among various types of shift work in firefighters.

### Conflicts of interest

The authors declare that there are no conflicts of interest.

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### Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.shaw.2019.05.003>.

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