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ORIGINAL ARTICLE

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Sleeping, sleeping environments, and human errors in South Korean male train drivers

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Abstract

Objectives: Reducing human errors caused by daytime sleepiness among train drivers is important to prevent train accidents. Our purpose of the study was to investigate the association among sleep, workplace sleeping environments, and human errors.

Methods: We recruited 144 South Korean train drivers belongs to the Korean Railroad Corporation. This cross-sectional data was analyzed to investigate the association of insomnia (insomnia severity index), sleep quality (Pittsburgh sleep quality index), obstructive sleep apnea (Berlin questionnaire), and daytime sleepiness (Epworth scale) with human error and near-miss experiences. We examined whether human error and near-miss events were associated with various sleeping environments at work and at home after adjusting for the sleep indices.

Results: The experience of human errors was associated with insomnia and daytime sleepiness, and near-miss events were associated with insomnia among South Korean drivers. Sleeping environments including cold temperature and odor were related to both human errors and near-miss events among South Korean train drivers, after adjusted for age, working years, shiftwork, obesity, smoking, binge drinking, regular exercise, caffeine consumption, sleep quality, severity of insomnia, obstructive sleep apnea, and daytime sleepiness.

Dong-Wook Lee and Seog Ju Kim contributed equally to this work.

Work Performed: Seoul National University Hospital.

Conclusions: The train drivers' workplace sleeping environment is significantly associated with human error events and near-miss events after adjusting for sleep quality, insomnia, obstructive sleep apnea, and daytime sleepiness. To prevent train accidents caused by human errors, more attention is necessary for improving workplace sleeping environments.

KEYWORDS

human errors, sleep hygiene, sleeping environments, train drivers

1 | INTRODUCTION

During the operation of railway vehicles, accidents and incidents occur by derailment, collision, damage, or fire, and these are often accompanied by personal injury. In South Korea, the number of railway accidents is continuously decreasing. The total number of railway accidents in 2011 was 277; in 2016, it was 123. This decline has been attributed to overall improvement in the railway environment, the expansion of safety facilities, and the promotion of public safety, including continuous improvement of facilities as seen in double lines, electric railways, and increased automation, as well as the introduction of advanced vehicles and modernization of maintenance equipment.[1] However, efforts to address accidents caused by human errors are still insufficient.

According to the Federal Railroad Administration, 38% of railway accidents were caused by human factors, such as improper operation of track switches or failure to determine that the track ahead is clear before beginning a shoving movement, rather than by facilities or systemic factors. Therefore, it is necessary to consider the possibility that some accidents attributed to human factors could be prevented by improvements in facilities.[2] A job analysis for train drivers showed that driving a train requires memory processes based on years of experience, the ability to work under time pressure, control of physiological processes, and tolerance for highly regulated work.[3] In general, the main issue in terms of preventing human errors by train drivers was regarded as post-traumatic stress disorder following a train accident/incident.[4,5] However, sleepiness and decreased job performance associated with shiftwork, irregular sleep times, stress related to railway accidents or incidents, and specific regulatory demands were also of concern among train drivers.[6,7]

Sleep problems, which has been identified as one cause of human error, can lead to railway accidents and incidents not only by incidental loss of consciousness but also through reduced cognitive and psychomotor functioning, which has been likened to the effects of alcohol.[8] Sleep and fatigue is associated with age, insomnia, caffeine consuming, and depressive disorders, and it could result in driving accidents or sickness absenteeism.[9-11] In addition, it has been reported that the differences in quality and duration between sleep at home and sleep at work among drivers.[12,13] However, it has yet to be studied that the role of sleeping environments among the association between sleep, sleeping environments, and human errors.

The purpose of this study was to investigate workplace sleeping environments related to the associations among daytime sleepiness, the experience of human errors, and the experience of a "near-miss" with the aim of suggesting ways to reduce human errors by sleeping environments that increase their likelihood among train drivers.

2 | SUBJECTS AND METHODS

2.1 | Study population

Train drivers were recruited as participants by The Human Error Research Committee, which was established by the nationwide railway consortium in South Korea, the Korean Railroad Corporation (KORAIL), as a means for researchers to study ways to prevent accidents and promote workers' health. The Psychology Division of the Human Error Research Committee was created at Seoul National University Hospital in 2013. This study was approved by the ethics committee of Seoul National University Hospital, Seoul, South Korea. Subjects were recruited by voluntary applications as part of a project to train KORAIL drivers from 17 KORAIL offices. Witten informed consent was obtained from all participants. Of 159 train drivers who participated in the program, those with incomplete answers for the sleep-related indices or sleep environment questions and those with missing information regarding age, gender, shiftwork, height, weight, smoking status, alcohol consumption, regular exercise, or caffeine consumption were excluded. One female participant was also excluded. The final sample size used in this study was 143.

2.2 | Sleep-related indices

The Pittsburgh Sleep Quality Index (PSQI) is a self-reported questionnaire for assessing sleep quality and sleep disturbances. The PSQI consists of 19 individual items related to subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and sleep-related daytime dysfunction, and it yields a global PSQI score of 0-21. Buysse et al reported that a global PSQI score >5 showed diagnostic sensitivity of 89.6% and specificity of 86.5% in distinguishing good and poor sleepers.[14] Therefore, we set the cut-off point for the PSQI score at 5. The reliability and validity of the Korean version of PSQI were established previously.[15]

The Epworth Sleepiness Scale (ESS) is a self-administered questionnaire that measures the level of daytime sleepiness. ESS consists of questions that assess the degree of sleepiness in eight situations, and each item is given a rating of 0-3.[16] We set a cut-off point for ESS at 10, as this cut-off was shown to have high sensitivity and high specificity.[17] The Korean version of ESS was previously investigated for its reliability and validity.[18]

The Insomnia Severity Index (ISI), a self-reporting tool designed to assess the severity of insomnia, is composed of seven items, each scored on a 5-point Likert scale. The ISI measures the severity of problems with sleep onset, sleep maintenance, and early morning awakening, as well as sleep dissatisfaction, interference of sleep problems with daytime functioning, noticeability of sleep problems by others, and distress caused by sleep difficulties. Those with ISI scores of 8 or higher can be classified as having sub-threshold insomnia at a minimum.[19] The Korean version of ISI has been assessed for reliability and validity.[20]

The Berlin Questionnaire (BQ), a product of the Conference on Sleep in Primary Care, held in April 1996 in Berlin, Germany, is a commonly used tool to identify those at high risk for obstructive sleep apnea (OSA).[21] The BQ is a self-reported questionnaire addressing risk factors for OSA and consists of three categories of questions: category 1 includes five items on snoring; category 2 is composed of three items on daytime sleepiness and one additional question on the severity of daytime sleepiness; and category 3 comprises a single item on hypertension. Considering respondents' weight status, those who are positive in at least two BQ categories are classified as at high risk for sleep apnea. The consistency and reliability of the Korean version of BQ were established previously.[22]

2.3 | Questionnaire about sleeping environments

Participants were asked about the degree of sleep disturbance attributable to the following factors: roommates, noise, light, hot temperature, cold temperature, insects, odors, ventilation, dust, and condition of bedding. Questions about the degree of sleep disturbance caused by each of these factors were answered separately about the bedrooms at home and the accommodation at work (regardless of shiftwork, train drivers frequently sleep in an accommodation provided by the subject company, depending on the final destination of their work schedule). In response to each item, participants selected one of the following: "severely disturbed," "moderately disturbed," "mildly disturbed," and "not at all disturbed." We classified participants into disturbed (mildly to severely disturbed) and non-disturbed groups (not at all disturbed).

2.4 | Other variables

Demographic variables and other information about participants were obtained using structured questionnaires regarding age, gender, years working as a train driver, shiftwork, height, weight, smoking status, alcohol consumption, regular exercise (moderate-intensity exercising three or more times per week at least 40 minutes each time), and caffeine consumption. Age at the time of the interview was categorised as follows: under 35, 35-44, 45-54, and 55 years or above. Participants answered "yes" or "no" to the following question about shiftwork status: "Have you ever worked more than once a week or at least 15 hours a week during nighttime between 10 PM and 6 AM?" If the answer was "yes," the total years of shiftwork was also recorded. Height and weight were asked directly of participants, and body mass index (BMI) was calculated by using these parameters. Obesity was defined as BMI ≥25.

2.5 | Human error and near-miss events

Subjects were asked about their experiences of human error events as follows: "Have you ever made a mistake (including minor mistakes) during your driving service?" Experiences of near-miss events were solicited using the following question: "Have you ever come close to making a mistake during your driving service?" In both questions, the responses were categorised dichotomously, that is, as having had these experiences or not.

2.6 | Statistical analysis

The distributions of experiences of human error and experiences of near-misses were investigated according to demographic variables. Chi-squared tests were performed to examine differences in the experiences of human error and experiences of near-misses by each variable. Next, we examined the association of sleep-related indices (sleep quality, insomnia, OSA, daytime sleepiness) with human error and near-miss experiences using multivariate logistic regression analysis with adjustment for potential confounders such as age, years working as a train driver, shiftwork, obesity, smoking status, regular exercise, and caffeine consumption in model 1. Model 2 was constructed by entering sleep quality, insomnia, OSA, and daytime sleepiness in the single model, with adjustment for potential confounders used in model 1. Finally, multivariate logistic regression analyses were performed to investigate whether human error and near-miss events were associated with various sleeping environments at work and at home. We constructed two logistic regression models. Model 1 considered the association between the sleeping environment and human error and that between the sleeping environment and near-miss events adjusting for age, working years, shiftwork, obesity, smoking, binge drinking, regular exercise, and caffeine consumption. Model 2 was additionally adjusted for sleep quality, insomnia, OSA, and daytime sleepiness. A Bonferroni correction was applied for the testing of 10 sleeping environments at workplace to address the issue of multiple comparisons (corrected significance level: $P < 0.005$). Statistical analyses were performed using SAS FREQ and SAS LOGISTIC procedures (Version 9.4; SAS Institute, Inc, Cary, NC), and statistical significance was defined as two-sided $P \leq 0.05$.

3 | RESULTS

Table 1 shows the characteristics of the study participants. All subjects were men and the mean age was 44.5 (±7.2) years. The mean duration of service was 19.4 (±8.2) years and 79.9% of train drivers were involved in shiftwork. Of the 143 train drivers, 60 (42.0%) reported having experienced a human error event and 100 (69.2%) reported having experienced a near-miss event. Experiences of human error events

TABLE 1 The characteristics of participated South Korean train drivers

	n (%)	Experiences of a human error event n (%)	Experiences of a near-miss event
Total	143 (100)	60 (42.0)	99 (69.2)
Age			
~35	12 (8.4)	4 (33.3)	8 (66.7)
35~45	60 (42.0)	24 (40.0)	40 (66.7)
45~55	63 (44.1)	28 (44.4)	45 (71.4)
55~	8 (5.6)	4 (50.0)	6 (75.0)
Years			
≤20	71 (49.7)	27 (38.0)	48 (67.6)
>20	72 (50.4)	33 (45.8)	51 (70.8)
Shiftwork			
No	29 (20.3)	8 (27.6)	15 (51.7)*
Yes	114 (79.7)	52 (45.6)	84 (73.7)
Body mass index			
<25 kg/m^2	105 (73.4)	38 (36.2)*	75 (71.4)
≥25 kg/m^2	38 (26.6)	22 (57.9)	24 (63.2)
Smoking			
Non-smoker	103 (72.0)	42 (40.8)	76 (73.8)
Current-smoker	40 (28.0)	18 (45.0)	23 (57.5)
Binge drinking			
<1/wk	84 (58.7)	31 (36.9)	57 (67.9)
≥1/wk	59 (41.3)	29 (49.2)	42 (71.2)
Regular Exercise[a]			
Yes	104 (72.7)	43 (41.4)	70 (67.3)
No	39 (27.3)	17 (43.6)	29 (74.4)
Caffeine Drink			
<1cup/d	30 (21.0)	12 (40.0)	22 (73.3)
≥1cup/d	113 (79.0)	48 (42.5)	77 (68.1)

[a]Moderate-intensity exercising three or more times per week at least 40 min each time.

*$P < 0.05$, the chi-squared test was performed to compare experiences of a human error event and experiences of a near-miss event among categories.

TABLE 2 Results of the logistic regressions for the association between daytime sleepiness-related indices and experiences of a human error event

		Experiences of a human error event		
		Frequency	Model 1[a]	Model 2[b]
Sleep Indices	n (%)	n (%)	OR (95% CI)	OR (95% CI)
Sleep quality				
PSQI ≤ 5	95 (66.4)	35 (36.8)	Reference	Reference
PSQI > 5	48 (33.6)	25 (52.1)	1.62 (0.76-3.47)	0.61 (0.23-1.62)
Insomnia				
ISI < 8	84 (58.7)	23 (27.4)	Reference	Reference
ISI ≥ 8	59 (41.3)	37 (62.7)	5.25 (2.33-11.83)**	4.88 (1.89-12.61)*
OSA				
No	117 (81.8)	43 (36.7)	Reference	Reference
Yes	26 (18.2)	17 (65.4)	2.63 (0.92-7.53)	1.63 (0.61-5.22)
Daytime sleepiness				
ESS < 11	127 (88.2)	46 (36.5)	Reference	Reference
ESS ≥ 11	17 (11.8)	14 (82.4)	11.28 (2.64-48.28)*	7.22 (1.59-32.77)*

Abbreviations: CI, confidence interval; ESS, Epworth sleepiness scale; ISI, Insomnia severity index; OR, odd ratio; OSA, obstructive sleep apnea; PSQI, Pittsburgh Sleep Quality Index.

[a]Adjusted for age, working years, shiftwork, obese, smoking, binge drinking, regular exercise, and caffeine consumption.

[b]Model 1 + adjusted for sleep quality, insomnia severity, OSA, daytime sleepiness.

*$P < 0.05$,

**$P < 0.001$.

were associated with higher BMI and experiences of near-miss events were associated with shiftwork.

Tables 2 show results on the sleep-related indices and the results of logistic regressions for experiences of human error. Of the 143 participants, 48 (33.3%) had PSQI scores above the cut-off value (>5), 59 (41.3%) had ISI scores above the cut-off value (≥8), 26 (18.2%) were identified as being at high risk for obstructive sleep apnea, and 17 (11.8%) had ESS scores above the cut-off value (>10). We found significant associations among daytime sleepiness, insomnia, and the experience of human error events. After adjusting for potential confounders, the ORs of human error with insomnia and daytime sleepiness were 5.25 (95% CI: 2.33-11.83) and11.28 (2.64-48.28), respectively. In the model 2, analyzed sleep quality, insomnia, OSA, daytime sleepiness in the single model, the ORs for human errors with insomnia and OSA were 4.88 (95% CI: 1.89-12.61), and 7.22 (95% CI: 1.59-32.77), respectively.

Experiences of near-miss event were associated with insomnia, OSA, daytime sleepiness after adjusting for age, working years, shiftwork, obese, smoking, binge drinking, regular exercise, and caffeine consumption (Table 3). Insomnia, OSA, and daytime sleepiness were associated with near-miss events with ORs of 6.91 (95% CI: 2.51-19.02), 5.13 (95% CI: 1.36-19.34), and 8.65 (1.02-73.42), respectively. When sleep-related indices were analyzed in the same model (model 2), insomnia was significantly associated with experiences of a human error event with OR of 7.40 (95% CI: 2.23-23.89).

Table 4 shows the logistic regression analysis among the environmental variables associated with sleep hygiene at home and at work, the experience of human error, and the experience of a near-miss event. Among the factors of the home sleeping environments, light, cold temperature, and bedding condition were significantly associated with the experience of human error in Model 1. However, these associations were not significant after additionally adjusting for the sleep quality, insomnia, OSA, and daytime sleepiness in Model 2. Factors in the workplace sleeping environment were more strongly related to human error events. Cold temperature (OR = 3.65, $P = 0.003$), insects (OR = 4.80, $P = 0.002$), odors (OR = 6.25, $P < 0.001$), ventilation (OR = 8.67, $P < 0.001$), dust (OR = 4.41, $P = 0.001$), and bedding conditions (OR = 4.91, $P = 0.002$) were significantly associated with human error events in Model 1. After the additional adjustments, cold temperature (OR = 4.77, $P = 0.002$), insect (OR = 6.59, $P = 0.001$), odor (OR = 5.93, $P = 0.001$), and ventilation (OR = 7.77, $P < 0.001$) was significantly associated with human errors in Model 2. In terms of the experience of a near-miss event, sleeping environment at home was not significant factor. Factors in the workplace sleeping environment associated with near-miss events in Model 1 included

TABLE 3 Results of logistic regressions for the association between daytime sleepiness-related indices and experiences of a near-miss event

		Experiences of a near-miss event		
		Frequency	Model 1[a]	Model 2[b]
Sleep Indices	n (%)	n (%)	OR (95% CI)	OR (95% CI)
Sleep quality				
PSQI ≤ 5	95 (66.4)	63 (66.3)	Reference	Reference
PSQI > 5	48 (33.6)	36 (75.0)	1.40 (0.59-3.31)	0.51 (0.17-1.53)
Insomnia				
SI < 8	84 (58.7)	46 (54.8)	Reference	Reference
ISI ≥ 8	59 (41.3)	53 (89.8)	6.91 (2.51-19.02)**	7.40 (2.23-23.89)*
OSA				
No	117 (81.8)	77 (65.8)	Reference	Reference
Yes	26 (18.2)	22 (86.6)	5.13 (1.36-19.34)*	3.53 (0.86-14.58)
Daytime sleepiness				
ESS < 11	127 (88.2)	83 (65.9)	Reference	Reference
ESS ≥ 11	17 (11.8)	16 (94.1)	8.65 (1.02-73.42)*	4.48 (0.48-41.34)

Abbreviations: CI, confidence interval; ESS, Epworth sleepiness scale; ISI, Insomnia severity index; OR, odd ratio; OSA, obstructive sleep apnea; PSQI, Pittsburgh Sleep Quality Index.

[a]Adjusted for age, working years, shiftwork, obese, smoking, binge drinking, regular exercise, and caffeine consumption.

[b]Model 1 + adjusted for sleep quality, insomnia, OSA, daytime sleepiness.

*$P < 0.05$,

**$P < 0.001$

roommates (OR = 3.43, P = 0.003), cold temperature (OR = 3.52, P = 0.002), odor (OR = 5.01, $P < 0.001$), ventilation (OR = 3.65, P = 0.002), dust (OR = 3.23, P = 0.004), and bedding condition (OR = 3.99, P = 0.003). After additionally adjusting for sleep quality, insomnia, OSA, and daytime sleepiness, cold temperature (OR = 5.37, P = 0.002) and odor (OR = 4.99, $P < 0.001$) showed significant associations with near-miss events.

4 | DISCUSSION

We found that experiences of human error events and near-miss events were significantly associated with sleep-related indices among South Korean train drivers. Human errors were associated with insomnia and daytime sleepiness, and near-miss events were associated with insomnia with adjustments for sleep-related indices including each other. Furthermore, environmental factors related to sleep conditions were significantly associated with such events. Cold temperatures and odors in workplace accommodation were especially related to both human error and near-miss events after adjusting for age, working years, shiftwork, obesity, smoking, binge drinking, regular exercise, caffeine consumption, sleep quality, insomnia, OSA, and daytime sleepiness. Insect and ventilation issues were significantly associated with human errors events.

Our results showed that, among South Korean male train drivers, the prevalence of daytime sleepiness was 11.8%, as defined by ESS scores ≥11, and that of OSA was 18.2%, as defined by BQ scores. Previous research examined the relationship between daytime sleepiness and related factors among train drivers and train accidents or incidents. Among Japanese public transportation drivers, 4.7% had severe daytime sleepiness and 3.7% had OSA.[23] A study conducted with 226 train drivers in Greece found that 7.1% of train drivers had severe daytime sleepiness, defined as ESS scores ≥11, and that 62% of train drivers had sleep-disordered breathing including OSA, as measured by polysomnography.[24] Among 280 Finnish train drivers, the prevalence of severe sleepiness, defined as Karolinska Sleepiness Scale scores ≥7, was 35.7%.

Sleep problems has been regarded as a major cause of driving accidents.[25,26] Insomnia, poor sleep quality, and daytime sleepiness can be caused by poor sleep quality, sleep-disordered breathing, psychiatric disorders, poor sleep hygiene, work conditions, and physical illness.[27,28] We found that insomnia was associated with human error events and near-miss events, and daytime sleepiness was associated with human errors among South Korean train drivers. These results are similar to those from studies on the association between sleepiness and vehicle driving. Recently, a prospective cohort study, part of the Sleep Heart Health Study, which enrolls 3,201 members of the general population in the US, reported that daytime sleepiness (ESS ≥11) was associated

TABLE 4 The associations between sleeping environments, the experience of human error, and the experience of near-miss event among South Korean train drivers

	Disturbed	Human error		Near-miss event	
		Model 1[a]	Model 2[b]	Model 1[a]	Model 2[b]
	n (%)	OR (99.5% CI)	OR (99.5% CI)	OR (99.5% CI)	OR (99.5% CI)
Bedrooms at home					
Roommates	41 (28.5)	1.25 (0.40-3.92)	0.93 (0.25-3.46)	1.65 (0.45-6.01)	1.25 (0.30-5.27)
Noise	41 (28.5)	1.65 (0.52-5.30)	1.31 (0.33-5.22)	2.13 (0.53-8.61)	1.85 (0.37-9.28)
Light	37 (25.7)	3.09 (0.85-11.30)	2.73 (0.59-12.67)	3.17 (0.64-15.75)	2.79 (0.43-17.92)
Hot temperature	39 (27.1)	1.76 (0.54-5.78)	1.59 (0.40-6.35)	2.15 (0.55-8.45)	1.67 (0.35-7.91)
Cold temperature	38 (26.4)	2.33 (0.69-7.88)	2.44 (0.60-9.88)	1.38 (0.36-5.21)	1.22 (0.27-5.50)
Insect	45 (31.3)	1.50 (0.49-4.59)	1.22 (0.31-4.78)	2.06 (0.57-7.45)	1.77 (0.39-8.16)
Odor	31 (21.5)	1.41 (0.40-5.04)	1.25 (0.27-5.72)	1.89 (0.42-8.43)	2.06 (0.35-12.18)
Ventilation	32 (22.2)	1.89 (0.54-6.68)	1.87 (0.42-8.18)	1.36 (0.34-5.40)	1.17 (0.23-5.97)
Dust	27 (18.8)	1.61 (0.41-6.29)	1.46 (0.31-6.95)	1.37 (0.29-6.41)	1.25 (0.21-7.40)
Bedding condition	34 (23.6)	2.77 (0.75-10.21)	2.13 (0.48-9.44)	2.02 (0.44-9.16)	1.59 (0.28-9.07)
Accommodations at workplace					
Roommates	97 (67.4)	3.07 (0.93-10.17)	1.89 (0.48-7.41)	3.43 (1.07-10.97)*	2.35 (0.64-8.59)
Noise	115 (79.9)	2.63 (0.64-10.88)	3.31 (0.59-18.58)	2.76 (0.74-10.30)	3.37 (0.68-16.70)
Light	64 (44.4)	2.70 (0.88-8.24)	2.23 (0.60-8.29)	3.08 (0.90-10.51)	2.62 (0.62-10.98)
Hot temperature	97 (67.4)	2.92 (0.86-9.95)	2.94 (0.77-11.16)	2.46 (0.76-7.94)	2.66 (0.71-9.90)
Cold temperature	96 (66.7)	3.65 (1.07-12.54)*	4.77 (1.14-19.94)*	3.52 (1.10-11.27)*	5.37 (1.30-22.22)*
Insect	108 (75.0)	4.80 (1.18-19.52)*	6.59 (1.27-34.22)*	3.09 (0.90-10.55)	3.36 (0.80-14.08)
Odor	87 (60.4)	6.25 (1.73-22.56)*	5.93 (1.37-25.62)*	5.01 (1.48-16.95)*	4.99 (1.21-20.54)*
Ventilation	86 (59.7)	8.67 (2.21-34.04)*	7.77 (1.69-35.66)*	3.65 (1.17-11.46)*	2.78 (0.80-9.73)
Dust	86 (59.7)	4.41 (1.26-15.48)*	3.39 (0.80-14.28)	3.23 (1.02-10.20)*	2.25 (0.63-8.06)
Bedding condition	112 (77.8)	4.91 (1.14-21.04)*	4.86 (0.95-24.89)	3.99 (1.06-15.04)*	3.61 (0.83-15.75)

Abbreviations: CI, confidence interval; OR, odd ratio; OSA, obstructive sleep apnea.

[a]Adjusted for age, working years, shiftwork, obese, smoking, binge drinking, regular exercise, and caffeine consumption.

[b]Model 1 + adjusting for sleep quality, insomnia, OSA, daytime sleepiness.

*$P < 0.005$, a Bonferroni correction was applied for the multiple testing of 10 sleeping environments at workplace.

with motor vehicle crashes in the last year.[29] A meta-analysis found that OSA, one cause of daytime sleepiness, was significantly associated with increased risk of vehicle accidents.[30] Daytime sleepiness can be induced by OSA. Data from the Wisconsin Sleep Cohort also showed that apnea–hypopnea events during sleep, which are variations in the severity of OSA, had a dose-response relationship with motor vehicle accidents.[31] A cross-sectional study with 5,480 train drivers found that poor sleep quality, categorised as PSQI >5, was associated with human error events in the past 5 years.[32]

We found that human error events and near-miss events were significantly associated with the workplace sleeping environment. Working schedules often require that train drivers sometimes sleep at their workplace, and the sleeping environment at work could contribute to train accidents/incidents. It has been studied that poor sleeping environments are associated with decreased sleep quality. For example, recent experimental study with polysomnography reported that cold sleeping environments was related with increased sleep onset latency and decreased slow wave sleep.[33] Other factors such as environmental noise and bed firmness were also associated with sleep quality and/or OSA.[34,35] As considering those who experienced sleep deprivation showed decreased vigilance and increased response times even when they did not complain of severe sleepiness,[36,37] decreased sleep quality associated with sleeping environments could results in disastrous result. It has also been studied that decreased sleep quality is associated with occupational accidents. A prospective cohort study with 47,860 participants and 20 years of follow-up period reported self-rated sleep difficulties is associated with fatal occupational accidents.[38]

We found that several inadequate conditions of sleeping environments the workplace are associated with human error events and near-miss events. Near-miss events and accidents related to the human error are likely to share a similar causal pathway.[39,40] In our study, cold temperature and odor were significantly and strongly associated with human error events and near-miss events. However, insects and ventilation were significantly associated with human errors events but not for near-miss events, although the directions of the associations were similar in those factors. To reduce the risk of human error events and near-miss events, it is necessary to improve the sleep quality, daytime sleepiness, and vigilant attention of train drivers by improving the sleeping environment at work, especially with regard to temperatures, insects, odor and ventilation issues.

Our results show that the association between sleeping environments at work, human error events and near-miss events after adjusting for sleep quality, insomnia, OSA and daytime sleepiness. Landry et al studied that comparing subjective sleep quality measured by PSQI and objective sleep quality measured by actigraphy and concluded that there is a quite difference between each other.[41] The other study reported that participants tend to underestimate sleep onset latency and the number of awakening comparing to objective indicators measured by polysomnography.[42] In this perspective, the remaining association between sleeping environments and human error after adjusting for sleep-related variables could be interpreted the actual sleep quality may be worse than the quality of sleep reported on the questionnaire. Furthermore, these additional and unrecognized burden were partly contributed by sleeping environments at workplace.

Sleeping environments at home were not associated with human errors and near-miss events in our study. However, considering previous studies that suggested sleeping environments including thermal environment, noise and bed firmness be associated with sleep quality and/or OSA,[33-35,43] the results of our study could not be interpreted as sleeping environments at works are only important for sleep quality of train workers. Jay et al reviewed articles related to sleeping at work and concluded that sleep at home tends to be longer and more efficient and is the familial environment for workers.[13] Furthermore, as factors such as temperatures, lights, and bedding conditions can be adjusted by habitants, discomfort conditions for sleeping can be found frequently in the workplace than in the home. The participants of our study also reported more discomfort sleeping environments in the workplace than in the home. Our result shows that elevated but non-significant ORs of sleeping environments at home for human errors and near-miss events. However, these results could be derived from low statistical power due to fewer number of disturbed cases.

To our knowledge, this is the first study to identify factors that are significantly associated with human errors events and near-miss events among train drivers. However, several limitations to this study should be considered when interpreting the results. First, our study used a cross-sectional design, which makes it difficult to establish a causal association between sleep quality and human errors or between the sleeping environment and human errors. Therefore, we cannot rule out the possibility that train drivers with poor sleep quality and/or with severe daytime sleepiness are more sensitive to the sleeping environment at work than are others. Second, selection bias and the representativeness of our sample could affect the results, as we recruited voluntary participants by advertising the study in cooperation with the company. Furthermore, it is difficult to infer the direction of such bias because drivers may have under-reported human errors and/or over-reported sleep-related difficulties and problematic sleeping environments. Third, our study population included only train drivers with one company in South Korea; therefore, these results have limited applicability to populations in other countries and of other ethnicities.

The train drivers' workplace sleeping environment is significantly associated with human error events and near-miss events after adjusting for daytime sleepiness and insomnia. To reduce train accidents resulting from human errors among train drivers, more attention must be paid to issues such as sleep problems and the drivers' workplace sleeping environment.

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DISCLOSURE

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AUTHOR CONTRIBUTIONS

Conceptualization, D-WL, SJK, D-HK; methodology, NYS, WJL, DSL; formal analysis, D-WL; writing-original draft preparation, D-WL; writing-review and editing, SJK, S-HC, JHJ, D-HK; funding acquisition, JHJ, SJK; and supervision, D-HK

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