Sleep Inertia and Its Associates in Shift and Non-Shift Workers

Juseung Kang1,*, Jichul Kim1,*, Jooyoung Lee2, Hyewon Yeo1, Yunjee Hwang3, Somi Lee1, Sehyun Jeon1, and Seog Ju Kim1

1Department of Psychiatry, Sungkyunkwan University College of Medicine, Samsung Medical Center, Seoul, Republic of Korea
2Seoulgardenclinic, Seoul, Republic of Korea
3Department of Brain & Cognitive Engineering, Korea University, Seoul, Republic of Korea

These authors contributed equally to this work.

Keywords
Shift work; Sleep inertia; Depression; Sleepiness; Insomnia; Chronotypes.

INTRODUCTION

Sleep inertia is a short-term mental status immediately after awakening from sleep and is characterized by sleepiness, hypoarousal, and disorientation.1–3 During the sleep inertia period, impaired performances, including inhibitory control,4 psychomotor vigilance,5 and decision making,6 were found in various cognitive areas. Sleep inertia may induce critical accidents due to sleepiness and cognitive impairments.6

Sleep inertia is associated with various factors, including insomnia,7 sleepiness,8 chronotypes,9,10 and mood.11 As reported in previous studies, sleep disturbances and depressive mood were more frequently observed in shift workers (SWs) than in non-shift workers (NSWs).12,13 SWs may experience more sleep inertia. One previous study reported that laboratory-simulated night shifts could induce sleep inertia, although it did not compare sleep inertia between SWs and NSWs.14 Furthermore, the effects of sleep disturbances or depressive symptoms on suicidality were reported to be different between SWs and NSWs.12,13 The association between sleep/mood and sleep inertia would differ between SWs and NSWs. However, studies comparing sleep inertia or its associated factors between SWs and NSWs are lacking.

Additionally, the factors associated with sleep inertia have close and complicated relationships with each other. Given that insomnia, sleepiness, chronotypes, and depressive mood have been reported to have close and bidirectional causal relationships,16,17 the pathways to sleep inertia may vary. If the effects of sleep and mood on sleep inertia were different between SWs and NSWs, the mediation effects from sleep/mood on sleep inertia could also vary between SWs and NSWs.

The current study explored sleep inertia and its association with insomnia, daytime sleepiness, chronotypes, and depres-
sion in SWs and NSWs. Our first hypothesis was that SWs would have higher sleep inertia than NSWs. Our second hypothesis was that insomnia, daytime sleepiness, chronotypes, and depression would predict sleep inertia in both SWs and NSWs. Finally, our last hypothesis, which was exploratory, was that the direct or indirect effect of sleep or mood on sleep inertia would differ between SWs and NSWs.

METHODS

Participants

Initially, 1,254 participants (448 men and 806 women; 293 NSWs and 961 SWs) were recruited through online advertisements. The URL with the online questionnaires and consent form was delivered to the participants. As the number of middle-aged men and NSWs was not sufficient in the initially recruited participants, an additional 5,400 participants (2,693 men and 2,707 women; 1,800 NSWs and 3,600 SWs) were recruited through an online survey company (Macromill Embrain Co. Ltd., Seoul, Korea). This company sent an online survey form to their members who agreed to participate. The inclusion criteria were as follows: with a part- or full-time job and at least 18 years of age. The exclusion criterion was the inability to complete the online surveys. All procedures were implemented in accordance with the ethical standards of the institutional committees on human experimentation and the Declaration of Helsinki. The study protocol was approved by the Institutional Review Board of Samsung Medical Center (protocol code 2019-04-095). Informed consent was obtained from all participants.

The participants were classified as SWs or NSWs. Those with fixed working schedules and working during standard daylight hours (from 7 AM to 6 PM) were classified as NSWs. Those with rotating working schedules or working during nonstandard daylight hours were classified as SWs.18 Participants whose working schedules were difficult to classify (n=11) were excluded from the final analysis. Finally, 4,561 SWs (2,142 men and 2,419 women, aged 36.99±9.73 years) and 2,419 women, aged 37.80±9.73 years) participated in the current study. Among SWs, 212 worked during evening (from 3 PM to 11 PM), and 163 worked during nights (from 11 PM to 7 AM) with fixed schedules. The number of SWs whose schedules were rotating was 3,370. Work schedules were difficult to be predicted in 453 SWs. Work schedules could be changed by preference in 363 SWs. The mean duration of shift work of SWs was 97.49 month.

Data on the participants’ demographic characteristics, including sex, age, working hours, income, and job types, were collected. Income was graded from 1 (0 KRW monthly) to 6 (4,500,000 KRW monthly). Job types were categorized into three types (A [white collar: managers, professionals, and clerks], B [service: service workers and sales workers], and C [blue collar: skilled agricultural, craft, forestry and fishery workers, and related trades workers and elementary workers]) based on the Korean Standard Classification of Occupation.19

Questionnaires

To assess for sleep inertia, the Sleep Inertia Questionnaire (SIQ)1 was used. The SIQ is a self-report questionnaire comprising 23 items. Each item of the SIQ is rated from 1 to 5. A higher score indicates greater sleep inertia. The original version of the SIQ was translated into Korean language by a clinical psychologist who is bilingual in English and Korean, and translated version was reviewed by two Korean psychiatrists. In the current study, internal consistency coefficient of the SIQ was 0.94.

The short form of the Center for Epidemiological Studies Depression scale (CESD)20 was used to assess for depressive symptoms. The short form CESD is an 11-item self-report questionnaire with scores ranging from 0 to 33. Higher scores indicate a more severe depression. In the current study, the internal consistency coefficient of the CESD was 0.91.

The Insomnia Severity Index (ISI)21,22 was used to assess the severity of insomnia. ISI is a 7-item self-report questionnaire used to assess for initial/maintenance/terminal insomnia, satisfaction with sleep, daytime function impairment, noticeability of insomnia, and worries about sleep. Each item is rated from 0 to 4. Higher scores indicate more severe insomnia. In the current study, the internal consistency coefficient of the ISI was 0.89.

The Epworth Sleepiness Scale (ESS)23,24 was used to assess for daytime sleepiness. The ESS comprises 8 items, which asks the probability of dozing under common situations. Each item is rated from 0 (never doze) to 3 (high chance of dozing). A higher score indicates a greater propensity to fall asleep. In the current study, the internal consistency coefficient of the ESS was 0.79.

The Morningness–Eveningness Questionnaire (MEQ)25,26 was used to determine chronotype. Individuals with Morningness prefer to be active in the early morning (i.e., early birds), whereas those with eveningness prefer to be active in the late evening (i.e., late owls). The MEQ score ranges from 16 to 86. A higher MEQ score indicates more Morningness. In the current study, the internal consistency coefficient of the MEQ was 0.76.

Statistical analyses

The chi-square test was used to compare the categorical data (e.g., sex or job type). The differences in continuous variables between SWs and NSWs were compared using the indepen-
dent t-test or analysis of covariance (ANCOVA). To compare the sleep or mood variables between groups, we used the ANCOVA model with age, sex, income, working hours, and job type as covariates. The additional ANCOVA models were also used to compare the SIQ between groups after adding one of the sleep or mood variables (CESD, ISI, ESS, or MEQ) as a covariate. Another ANCOVA model to compare the SIQ between groups was performed after controlling for all the sleep or mood variables at the same time. A multiple linear regression model (dependent variable: SIQ; independent variables: CESD, ISI, ESS, or MEQ; covariates: age, sex, income, working hour, and job type) was created to assess the effect of sleep or mood on sleep inertia. Another multiple linear regression analysis was performed after including the working schedule (i.e., SW or NSW) as an additional independent variable. To examine whether the effect of mood/sleep on sleep inertia differed between SWs and NSWs, additional multiple regression models (dependent variable: SIQ; independent variables: shift schedule, mood/sleep [CESD, ISI, ESS or MEQ], interaction between shift schedule and mood/sleep; covariates: age, sex, income, working hours, and job) were also used. If the interaction effect was significant, model 7 of PROCESS was tested to examine the effect of mood/sleep variables on SIQ through other mood/sleep variables moderated by work schedules. PROCESS model 7 was applied to the mood/sleep variables with a significant interaction with work schedules on SIQ. Additionally, because the relationship between mood and sleep variables was close and complex, we considered all possible mediators (CESD, ISI, ESS, or MEQ) to examine the various pathways to sleep inertia. The study PROCESS macro used 5,000 bootstrapping samples to verify the indirect effects of the independent variable on the dependent variable through the moderator and mediator.²⁷ SPSS software (ver. 22.0; IBM Corp., Armonk, NY, USA) was used for all analyses. A p-value of <0.05 was considered statistically significant. The variance inflation factor (VIF) was analyzed for checking multicollinearity before each statistical analysis was computed. VIF value of all the predictors was not exceeded 5, which indicates no collinearity issue.²⁸ Highest VIF value was 4.14.

RESULTS

Demographic data and clinical characteristics

The sex proportion and income between SWs and NSWs were not significantly different. SWs were significantly younger than NSWs (t=3.10, p<0.01). SWs worked significantly longer times per week than NSWs (t=-8.47, p<0.001). The job type differed significantly between SWs and NSWs (χ²=213.23, p<0.001). The ratio of workers classified as A (white collar) in NSWs was higher than that in SWs.

Compared with NSWs, SWs had higher SIQ (F=81.73, p<0.001), CESD (F=84.51, p<0.001), ESS (F=19.77, p<0.001), and ISI (F=153.48, p<0.001) after controlling for age, sex, job type, working hours, and income (Table 1). SWs also had lower MEQ (F=89.60, p<0.001) than NSWs after controlling for age, sex, job type, working hours, and income. The group difference in SIQ remained significant after additionally controlling for CESD (F=23.53, p<0.001), ESS (F=71.60, p<0.001), ISI (F=12.26, p<0.001), and MEQ (F=44.55, p<0.001). However, the group difference in SIQ (F=0.00, p=0.97) was not significant after controlling for CESD, ESS, ISI, and MEQ at the same time.

Prediction of sleep inertia based on the clinical characteristics in each group

In the multiple regression analysis after controlling for age, sex, job type, working hours, and income (Table 2), CESD (β=0.61, p<0.001), ESS (β=0.34, p<0.001), ISI (β=0.53, p<0.001), and MEQ (β=0.33, p<0.001) predicted SIQ. In this regression model, these variables also predicted SIQ in both SWs and NSWs. The SIQ of SWs was predicted by their CESD (β=0.63, p<0.001), ESS (β=0.35, p<0.001), ISI (β=0.54, p<0.001), and MEQ (β=0.29, p<0.001). The CESD (β=0.55, p<0.001), ESS (β=0.31, p<0.001), ISI (β=0.49, p<0.001), and MEQ (β=-0.38, p<0.001) also significantly predicted SIQ in NSWs. However, the effect of working schedules on SIQ (β=0.01, p=0.98) was not significant when working schedules was added as an

Table 1. Demographic and mood/sleep characteristics of the study participants

<table>
<thead>
<tr>
<th></th>
<th>Non-shift workers</th>
<th>Shift workers</th>
<th>t, F, χ²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>37.80±9.73</td>
<td>36.99±9.84</td>
<td>t=3.10**</td>
</tr>
<tr>
<td>Sex (men)</td>
<td>999 (47.7)</td>
<td>2,142 (47.0)</td>
<td>t=0.34</td>
</tr>
<tr>
<td>Job type</td>
<td></td>
<td></td>
<td>χ²=213.22***</td>
</tr>
<tr>
<td>A (White collar)</td>
<td>1,674 (81.1)</td>
<td>2,829 (63.1)</td>
<td></td>
</tr>
<tr>
<td>B (Service)</td>
<td>227 (11.0)</td>
<td>970 (21.7)</td>
<td></td>
</tr>
<tr>
<td>C (Blue collar)</td>
<td>162 (7.9)</td>
<td>681 (15.2)</td>
<td></td>
</tr>
<tr>
<td>Work hours per week</td>
<td>28.24±18.33</td>
<td>32.66±20.36</td>
<td>t=-8.47***</td>
</tr>
<tr>
<td>Income†</td>
<td>4.23±0.99</td>
<td>4.22±1.00</td>
<td>F=0.54</td>
</tr>
<tr>
<td>CESD‡</td>
<td>7.11±5.83</td>
<td>8.75±6.30</td>
<td>F=84.51***</td>
</tr>
<tr>
<td>ESS‡</td>
<td>7.83±3.88</td>
<td>8.36±3.97</td>
<td>F=19.77***</td>
</tr>
<tr>
<td>ISI‡</td>
<td>6.16±2.72</td>
<td>6.97±3.00</td>
<td>F=153.48***</td>
</tr>
<tr>
<td>MEQ‡</td>
<td>47.15±7.87</td>
<td>44.96±8.09</td>
<td>F=89.66***</td>
</tr>
<tr>
<td>SIQ‡</td>
<td>49.48±14.45</td>
<td>53.40±14.79</td>
<td>F=81.73***</td>
</tr>
</tbody>
</table>

*p<0.01; **p<0.001; †ANOVA after controlling for age, sex, income, job type, and work hours per week; CESD, Center for Epidemiological Studies Depression Scale; ESS, Epworth Sleepiness Scale; ISI, Insomnia Severity Index; SIQ, Sleep Inertia Questionnaire; MEQ, Morningness–Eveningness Questionnaire

www.psychiatryinvestigation.org 3
Sleep inertia in shift workers

The multiple regression model examined the interaction effects between sleep or mood variables (CESD, ISI, ESS, or MEQ) and working schedules on SIQ. There were no significant interaction effects between ISI and shift schedules (β=0.02, p=0.24), and between ESS and shift schedules (β=0.02, p=0.21) on SIQ, indicating that the association between SIQ and ISI (or ESS) was not different between SWs and NSWs. In contrast, there were significant interaction effects between CESD and shift schedules (β=0.04, p<0.05) and between MEQ and shift schedules (β=0.09, p<0.001) on SIQ. The association between CESD and SIQ was stronger in SWs than in NSWs (Figure 1). The association between MEQ and SIQ was stronger in NSWs than in SWs (Figure 1).

PROCESS model 7 was applied to the mood/sleep variables (CESD or MEQ) that showed a significant interaction with work schedules on SIQ. The indirect effect of CESD on SIQ via ISI or ESS was not significantly moderated by work schedules. Additionally, the indirect effect of MEQ on SIQ via CESD or ISI was not significantly moderated by work schedules. The bootstrapping results showed that the indirect effect of CESD on SIQ via ESS was significantly moderated by work schedules (effect=-0.28, standard error [SE]=0.012, 95% confidence interval [CI]=0.003, 0.053). The conditional indirect effect of CESD on SIQ via ESS in SWs (effect=-0.124, SE=0.011, 95% CI=0.103, 0.147) was significantly stronger than that of NSWs (effect=-0.962, SE=0.096, 95% CI=0.073, 0.122) (Figure 2). Additionally, the indirect effect of MEQ on SIQ via ESS was significantly moderated by work schedules (effect=-0.048, SE=0.016, 95% CI=0.016, 0.080). The conditional indirect effect of MEQ on SIQ via ESS (effect=-0.050, SE=0.013, 95% CI=-0.077, -0.024) was significant in NSWs, but not in SWs (effect=-0.002, SE=0.010, 95% CI=-0.020, 0.017) (Figure 3).

DISCUSSION

In the current study, SWs showed higher sleep inertia than NSWs. Sleep inertia was associated with depression, sleepiness, insomnia, and chronotype, regardless of the participants’ work schedule. The effect of depression on sleep inertia, especially the indirect effect via sleepiness, was stronger in SWs. Contrarily, the effect of chronotype on sleep inertia, especially the indirect effect via sleepiness, was weaker in SWs. To the best of our knowledge, this is the first study to compare sleep inertia and its correlates/mediators between SWs and NSWs.

Consistent with our hypothesis, SWs demonstrated higher sleep inertia than NSWs, even after controlling for depression, sleepiness, insomnia, or chronotype. This finding suggests that the higher sleep inertia among SWs could not be explained by

Table 2. Association between sleep inertia and mood/sleep characteristics after controlling for age, sex, income, job type, and work hours

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Total group</th>
<th>Non-shift workers</th>
<th>Shift workers</th>
</tr>
</thead>
<tbody>
<tr>
<td>CESD</td>
<td>β=0.61***</td>
<td>β=0.55***</td>
<td>β=0.63***</td>
</tr>
<tr>
<td>ESS</td>
<td>β=0.34***</td>
<td>β=0.31***</td>
<td>β=0.35***</td>
</tr>
<tr>
<td>ISI</td>
<td>β=0.53***</td>
<td>β=0.49***</td>
<td>β=0.54***</td>
</tr>
<tr>
<td>MEQ</td>
<td>β=0.33***</td>
<td>β=0.38***</td>
<td>β=0.29***</td>
</tr>
</tbody>
</table>

***p<0.001. CESD, Center for Epidemiological Studies Depression Scale; ESS, Epworth Sleepiness Scale; ISI, Insomnia Severity Index; MEQ, Morningness–Eveningness Questionnaire

Figure 1. Association between mood/chronotype and sleep inertia in SWs and NSWs. Association between depression (A) chronotype (B) and sleep inertia in SWs and NSWs. A: The interaction effect of CESD and SW on sleep inertia was significant (β=0.04, p<0.05). The interaction effect of MEQ and SW on sleep inertia was significant (β=0.09, p<0.001). The lines are trend lines; the red line in (A) was 1.39x+39.69; the blue line in (A) was 1.48x+40.45; the red line in (B) was -0.72x+83.26; the blue line in (B) was -0.56x+78.79. CESD, Center for Epidemiological Studies Depression Scale; SIQ, Sleep Inertia Questionnaire; MEQ, Morningness–Eveningness Questionnaire; SWs, shift workers; NSWs, non-shift workers.
sleep disturbances or depressive symptoms alone. However, the difference in sleep inertia between SWs and NSWs became nonsignificant after simultaneously controlling for all sleep or mood variables. Furthermore, the work schedule could not predict sleep inertia after controlling for all sleep or mood variables at the same time. Therefore, the higher sleep inertia of SWs can be explained by the combined effect of depressive symptoms, sleepiness, insomnia, and evening-chronotype, rather than by the work schedule itself.

In the current study, in both SWs and NSWs, depressive symptoms, insomnia, sleepiness, and evening-chronotype were associated with sleep inertia. These findings are consistent with the data of previous studies investigating on the factors associated with sleep inertia. There were many suggestions as to why these factors induce sleep inertia. Short sleep time or poor sleep quality, which is common in persons with insomnia or depression, would produce more sleep inertia. Insufficient sleep, which is the most common cause of sleepiness, was also suggested to increase sleep inertia. Individuals with evening-chronotype would also have a higher risk of experiencing chronic sleep insufficiency due to social jetlag. Circadian dysregulation related to depression may also produce sleep inertia.

In the current study, the effect of depression on sleep inertia was stronger in SWs than in NSWs. Our data also showed that a stronger indirect effect via sleepiness (i.e., stronger depression–sleepiness association) could explain the stronger depression–sleep inertia association among SWs. The stronger depression–sleepiness association among SWs could be explained by rhythm flexibility. The rhythm flexibility indicates the stability of sleeping habits. The people whose sleep habit is flexible would sleep and work more easily even at unusual time. Depression is associated with a poor rhythm flexibility. Poor rhythm flexibility was closely related to shift work tolerance, i.e., adaptability to shift work schedule without damaging consequences. Poor rhythm flexibility may induce excessive sleepiness among SWs. Therefore, individuals with depression who have a poor rhythm flexibility may have difficulty in tolerating shift work-related sleepiness and shift work-related sleep inertia.

The current study also reported that the effect of evening-chronotype on sleep inertia was relatively weaker in SWs than in NSWs. This result would be associated with alignment of chronotype with work schedule. The peak of melatonin circadian rhythm was reported to be delayed by night shift work. As the peak of melatonin circadian rhythm were also later in evening chronotype, the circadian rhythm of evening chronotype would be more consistent with the circadian rhythm delay imposed by night shift. Sleep inertia is stronger under the circadian rhythm of evening chronotype than morning chronotype. The indirect effect of chronotype on sleep inertia via sleepiness was not significant. Therefore, evening chronotype could experience less shift work-related circadian misalignment and sleep inertia compared to morning chronotype. The indirect effect of chronotype on sleep inertia via sleepiness was not significant in SWs. People with the evening-chronotype were reported to be more adaptable to shift work than those with the morning chronotype. SWs with an evening-chronotype were also reported to exhibit more flexible sleep schedules and experience less sleepiness than SWs with a morning chronotype.
sleepiness and shift work-related sleep inertia.

The effect of mood or chronotype on sleep inertia could be associated with hormone such as melatonin or gene such as CLOCK. The rhythm of melatonin secretion was associated with chronotype or depression. The CLOCK gene was also associated with chronotype or depressive symptoms. Sleep inertia was also associated with melatonin and CLOCK gene. Therefore, the association between sleep inertia and mood/chronotype may be mediated by melatonin or CLOCK gene.

The countermeasures against sleep inertia with immediate effects have not yet been found. However, our results suggest that the management of mood or sleep disturbances would be helpful for reducing excessive sleep inertia. In particular, for SWs' sleep inertia, the management of depression symptoms and sleepiness would have potential effects.

The present study has several limitations. First, our study could not prove the causal relationship between work schedules and sleep inertia because our study design was cross-sectional. The causal relationship between work schedules and sleep inertia will be examined in a future longitudinal study. Second, all measurement tools were self-reported questionnaires. Sleep inertia was also assessed by self-reports. The variables including sleep or mood could also be measured by objective evaluation (e.g., polysomnography or structured psychiatric interviews). Future studies measuring sleep inertia based on the performance immediately after awakening would also be helpful. Third, Korean version of SIQ has not been validated. Although mental health experts translated the original version of SIQ into Koreans, there would be some issues in the reliability or the validity of Korean version of SIQ used in the current study. Fourth, the individual differences regarding shift work tolerance were not investigated in detail. Some individual differences related to shift work tolerance such as age, gender and chronotype were examined in the current study. However, other characteristics which were reported to be associated with shift work tolerance, such as internal locus of control and self-esteem, were not explored in the current study. Fifth, the present study did not collect work-related information such as the past shift work experiences of currently NSWs. More detailed information regarding shift work would be helpful. Lastly, as all participants were South Koreans, the applicability of our study results to other cultures may be limited.

In conclusion, SW experience more severe sleep inertia than NSWs. Depressive symptoms, sleepiness, insomnia, and chronotype were associated with sleep inertia among SWs and NSWs. The association between depressive symptoms and sleep inertia, especially those mediated by sleepiness, was more prominent among SWs. Contrarily, the association between chronotype and sleep inertia, especially those mediated by sleepiness, was more prominent among NSWs.

Availability of Data and Material

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

Author Contributions


ORCID iDs

Juseung Kang https://orcid.org/0000-0002-7778-2923
Jichul Kim https://orcid.org/0000-0002-7660-4252
Jooyoung Lee https://orcid.org/0000-0002-8774-7128
Hyewon Yeo https://orcid.org/0000-0002-4245-6933
Yunjee Hwang https://orcid.org/0000-0001-7246-9316
Somi Lee https://orcid.org/0000-0002-7443-2805
Sehyun Jeon https://orcid.org/0000-0002-6594-6536
Seog Ju Kim https://orcid.org/0000-0003-2467-5451

Funding Statement

This research was supported by the National Research Foundation of Korea (NRF) grant funded by the Korean government (MSIT) (2022R1A2C2008417), Brain Research Program through the National Research Foundation of Korea, funded by the Ministry of Science, ICT and Future Planning (No. 2020M3E5D9080561) and the Institute of Information & communications Technology Planning & Evaluation (IITP) grant funded by the Korea government (MSIT) (No.RS-2023-00221742).

Acknowledgments

None

REFERENCES

9. Balkin TJ, Badia P. Relationship between sleep inertia and sleepiness: cumulative effects of four nights of sleep disruption/restriction on per-

10. Trotti LM. Waking up is the hardest thing I do all day: sleep inertia and sleep drunkenness. Sleep Med Rev 2017;35:76-84.


43. Roig CA. The impact of circadian misalignment on health and wellness in medical students [dissertation]. Fort Worth, TX: University of North Texas Health Science Center at Fort Worth; 2020.


www.psychiatryinvestigation.org