Industrial Health 2022, **60**, 559–566

Original Article

Do holidays change subjective sleep length or sleep debt in shift work disorder?

Päivi VANTTOLA[1]*, Mikko HÄRMÄ[1], Christer HUBLIN[1], Katriina VIITASALO[2], Mikael SALLINEN[1, 3], Jussi VIRKKALA[1, 4] and Sampsa PUTTONEN[1]

[1]Finnish Institute of Occupational Health, Finland
[2]Finnair Health Services, Finland
[3]Department of Psychology, University of Jyväskylä, Finland
[4]Department of Clinical Neurophysiology, University of Helsinki and Helsinki University Hospital, Finland

Received October 13, 2020 and accepted February 3, 2022
Published online in J-STAGE February 15, 2022
DOI https://doi.org/10.2486/indhealth.2020-0215

Abstract: In shift work disorder (SWD), disturbed sleep acutely impairs employees' recovery, but little attention has been paid to sleep during longer recovery periods. We examined how holidays affect self-estimated sleep length, sleep debt, and recovery in cases of SWD. Twenty-one shift workers with questionnaire-based SWD and nine reference cases without SWD symptoms completed a questionnaire on recovery and sleep need. They also reported sleep length on two separate occasions: during a work period and after ≥ 2 weeks of holidays. Sleep debt was calculated by subtracting sleep length from sleep need. We used parametric tests to compare the groups and the periods. The groups reported shorter sleep on workdays than during holidays (median difference: SWD group 1.7 h, $p<0.001$; reference group 1.5 h; $p<0.05$). The SWD group's self-estimated sleep during holidays increased less above the sleep need (median 0.0 h) than the reference group's sleep (1.0 h, $p<0.05$). In addition, the SWD group reported good recovery from irregular working hours less often (14%) than the reference group (100%, $p<0.001$). Although holidays were generally associated with longer sleep estimates than workdays, employees with SWD experienced consistently less efficient recovery than those without SWD.

Key words: Circadian rhythm sleep-wake disorder, Day off, Excessive sleepiness, Free day, Insomnia, Non-workday, Shift work sleep disorder, Vacation

Introduction

Work schedules restrict shift workers' sleep on workdays. During weekly days off, individuals can time their sleep more freely and increase their sleep length to recover from work-related strain. The epidemiological literature suggests that habitual sleep of seven to eight hours is beneficial for health and that outside this range, the risk of mortality, for example, increases[1–3]. In laboratory conditions, the length of asymptotic sleep has been 8.2–8.9 h among young adults and 7.4 h among the elderly[4, 5]. During a longer holiday, the prior work schedule should not considerably affect the amount of sleep. De Bloom *et al*.[6] found that employees report approximately 40-min longer night sleep during (7.4 h) than before (6.7 h) a holiday period of at least two weeks. During days off, sleep length increases by ap-

*To whom correspondence should be addressed.
E-mail address: paivi.vanttola@ttl.fi

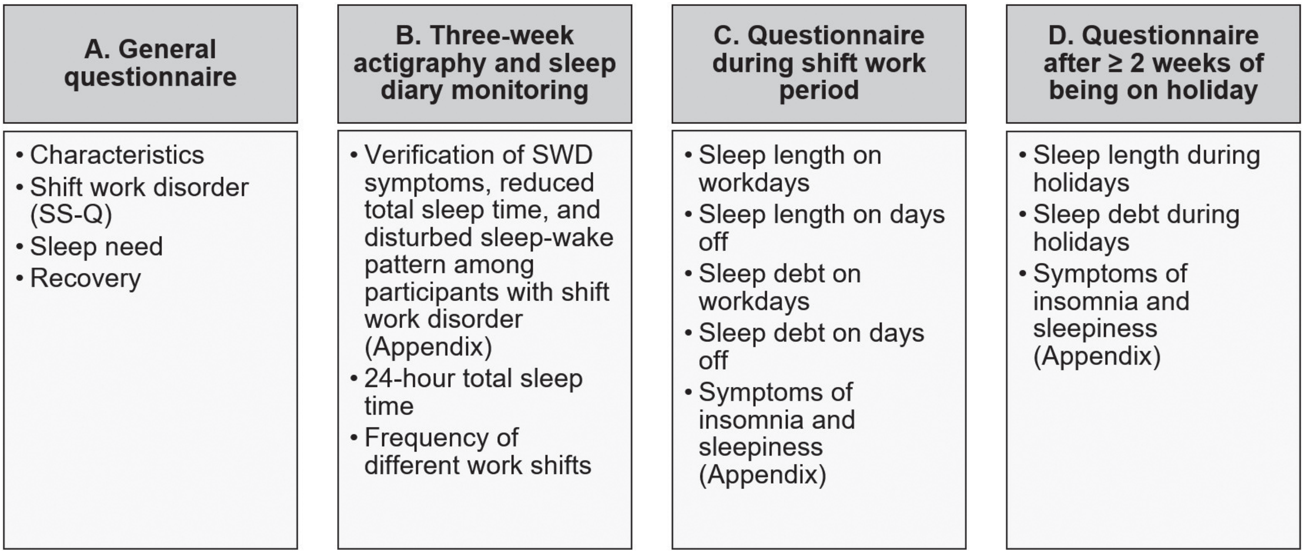

Fig. 1. Study design and variables/measures.

proximately 20–45 min in comparison to workdays[7–9], and sleep quality improves[9].

In shift work, sleep length decreases by up to four hours prior to morning shifts and between night shifts, and many shift workers tackle sleep loss with prophylactic and restorative napping[10]. In addition to morning and night shifts, short shift intervals typically restrict sleep length and cause sleepiness[11, 12], increasing the risk of shift work disorder (SWD)[13]. SWD is characterised by chronic shift work schedule-related insomnia and/or excessive sleepiness, based on the second[14] and third[15] editions of the International Classification of Sleep Disorders (ICSD-2 and ICSD-3, respectively). We recently concluded that approximately 6% of hospital night shift workers are affected by ICSD-3-based SWD[16]. The ICSD-3 requires a reduced total sleep time in addition to the primary symptoms of SWD. Night work and morning shifts – but not days off – have been associated with reduced sleep in SWD[17, 18]. Even so, Kalmbach *et al.*[19] have found that new rotating shift workers who develop SWD report shorter sleep on weekend nights than those who do not develop SWD.

Shift work increases the subjective need for recovery from work[20]. Consequently, shift workers experience more fatigue on days off than dayworkers, and report extended sleep length, probably due to their increased need for restorative sleep[21]. Field studies have shown that employees' sleep may be at its shortest directly after the last night shift[22] or on the first day off after a night shift[23], after which sleep duration increases. Garde *et al.*[22] indicated that after the last night shift, police officers' sleep improved with more consecutive recovery days. In addition, Haluza *et al.*[24] suggest that having three consecutive days off could improve recovery from shift work. Subjective sleepiness typically reverses after at least two nights of recovery sleep following a night shift[25]. We have previously found that in addition to inefficient sleep, SWD is associated with excessive sleepiness[26] and slower recovery[17] on weekly days off. Yet, although they could alleviate the symptoms of SWD, longer recovery periods are rarely studied among shift workers.

To examine recovery during holidays in cases of SWD, we compared shift workers with and without questionnaire-based SWD during work and holiday periods. In addition to their general questionnaire responses, we utilised their responses to questions on sleep length at two separate points of time: during a work period and after at least two weeks of being on holiday. We had two main hypotheses. First, we hypothesised that shift workers both with and without SWD would report longer sleep during holidays than on workdays. Secondly, we hypothesised that shift workers with SWD would experience longer sleep but similar sleep debt during holidays to those without SWD.

Subjects and Methods

Study design and setting

This observational study consisted of three questionnaires and a three-week sleep diary and actigraphy registration (Fig. 1A. general questionnaire, B. Sleep diary and actigraphy monitoring, C. questionnaire on shift work period, and D. questionnaire on holiday period) at different points of time between 2012 and 2013. The shift workers completed the questionnaire on the shift work period (Fig. 1C) either before or during the three-week sleep diary and actigraphy monitoring period (Fig. 1B). We used the sleep diaries and actigraphy to observe and verify that the shift workers' symptoms and shift schedules (Fig. 1B) were in accordance with the ICSD-3 criteria of SWD[17] between May 2012 and July 2013. The interval between the questionnaires on shift work (Fig. 1C) and holidays (Fig. 1D) varied from one to six months. The study protocol was approved by the Coordinating Ethics Committee of the Hospital District of Helsinki and Uusimaa (35/13/03/00/12). The study followed the requirements of the Helsinki Declaration. All the participants provided written informed consent.

Participants

The study included 54 full-time ground staff members of Helsinki Airport (Finland), whose shift schedules included early morning shifts (starting from 03:01 to 06:00) and/or night shifts (at least 3 h of work between 23:00 and 06:00 h), and evening shifts[17]. Eleven shift workers discontinued due to health, personal, or unknown reasons. To form and compare clear SWD and clear non-SWD (i.e., reference) case groups, and to simplify the interpretation of the results, we excluded a further 13 shift workers with milder SWD symptoms (only occurring 'rather often') who could not be distinctly classified as either SWD or reference cases (see criteria for the groups in 'Shift work disorder' section below)[17]. The final sample was composed of 21 SWD cases and nine reference cases.

General questionnaire

The general questionnaire included questions on background characteristics, SWD, recovery, and sleep (Fig. 1A). It was used to define SWD and to explore aspects of recovery on a general level.

Shift work disorder

We formed the study groups on the basis of the answers to the shift-specific questions on insomnia and sleepiness (SS-Q)[17]: 'How often do you 1) experience difficulties initiating sleep, 2) awaken during a sleep period, 3) experience difficulties falling asleep after awakening, 4) experience non-restorative sleep, 5) experience daytime sleepiness, and 6) experience difficulties staying awake at work, in relation to i) morning shifts, ii) evening shifts, iii) night shifts, and iv) two weeks of being on holiday (excluding Question 6)'? The participants used a four-point scale ('never/rarely', 'rather rarely', 'rather often', or 'often/continuously') to answer the sub-questions (i–iv) of all the questions (1–6). 'Not applicable' was also a response option.

To fulfil the criteria of SS-Q-based SWD case, the shift workers had to report symptoms of insomnia or sleepiness 'never/rarely' or 'rather rarely' after two weeks of being on holiday, and report at least one of the 'never/rarely' or 'rather rarely' occurring symptoms as 'often/continuously' in connection with morning, evening, and/or night shift. Nevertheless, one of the six symptoms could occur during the holiday period if at least one other symptom only occurred in connection with work shifts[17]. To fulfil the criteria of SS-Q-based reference case, the shift workers had to report symptoms of insomnia and sleepiness as 'never/rarely' or 'rather rarely' in relation to both shifts and holidays. However, like the SWD cases, no more than one holiday-related symptom could occur 'rather often' or 'often/continuously'[17].

To meet the ICSD-3 criteria of SWD, we used a three-week actigraphy and sleep diary monitoring (Fig. 1B and Appendix) to verify disturbed sleep-wake patterns and reduced total sleep time[17] and confirmed that the frequency of work shifts and the SWD symptoms were adequate[16, 17] (see Appendix T1–3). Our definition of SWD also complies with the circadian rhythm sleep-wake disorder – shift work type – in the 11th revision of the International Classification of Diseases[27].

Other general questionnaire variables

The participants responded to items on age (yrs), sex, chronotype (four-point scale from 'definitely a morning-type' to 'definitely an evening-type' dichotomised to morning/evening-type)[28], shift work experience (yrs), average length of shifts (h), obstructive sleep apnoea, sleep need (h)[17], and recovery from irregular working hours (four-point scale from 'poor' to 'good') (Fig. 1A).

Three-week actigraphy and sleep diary monitoring

The participants wore an actigraph Actiwatch AW7 (Cambridge Neurotechnology Ltd, Cambs, UK) on their non-dominant wrist for a three-week shift work period. We used Actiwatch Activity and Sleep Analysis 7 software (Cambridge Neurotechnology Ltd, Cambs, UK) to build a variable on average 24-hour total sleep time including workdays and days off (Fig. 1B) from one-minute epochs[17]. In addition, the participants filled in a sleep diary in which they reported shift start and end times at bedtime (Fig. 1B)[17].

Table 1. Sample characteristics

Variable	SWD							Reference							*p*
	n (group)	Mean	(SD)	Median	(IQR)	%	(n)	n (group)	Mean	(SD)	Median	(IQR)	%	(n)	
Sex (men)	21					76	(16)	9					78	(7)	1.000 [c]
Age (yr)	21	41	(8)					9	48	(7)					0.043 [a]
Morning chronotype	21					38	(8)	9					56	(5)	0.443 [c]
Sleep need (h)	21			8.0	(2.0)			9			7.0	(1.5)			0.030 [b]
24-hour TST (h) – actigraphy	21	6.7	(0.7)					9	7.1	(0.4)					0.066 [a]
Treated obstructive sleep apnoea	21					5	(1)	9					11	(1)	0.517 [c]
Shift work experience (yr)	21	17	(8)					9	23	(13)					0.183 [a]
Length of shifts (h)	21			9.0	(1.2)			9			9.7	(1.0)			0.156 [b]
Early morning shifts per month	10			5.5	(4.8)			5			5.3	(3.5)			0.499 [b]
Any morning shift per month	21			6.8	(3.6)			8			5.6	(3.5)			0.250 [b]
Evening shifts per month	21			4.3	(1.7)			9			4.1	(1.7)			0.666 [b]
Night shifts per month	17			5.0	(1.6)			8			4.6	(3.8)			0.884 [b]

IQR, interquartile range
TST, total sleep time
[a] Independent samples *t-test*
[b] Mann–Whitney *U-test*
[c] Fisher's Exact Test
[d] 'Absolutely morning type' or 'more morning than evening type'

Questionnaires on work and holiday periods

The participants completed questionnaires during a visit to a medical centre once during a shift work period (Fig. 1C) and once after at least two weeks of being on holiday (Fig. 1D). The participants answered the questions 'How long during the last two weeks have you slept on average per 24 h, including naps 1) on workdays (sleep length on workdays, h and min) and 2) on days off/holidays (answering during a work period: sleep length on days off; answering after holidays: sleep length during holidays; h and min)?'. We calculated sleep debt for workdays, days off, and holidays separately by subtracting self-reported sleep length on these days from self-reported sleep need[17, 29].

To enable us to evaluate the presence of SWD symptoms in relation to the questionnaire responses on sleep length, the participants also estimated the occurrence of symptoms of insomnia and sleepiness in the last two weeks (Fig. 1C and D) as part of the questionnaires on work and holiday periods (see Appendix T4). The comparison of shift work and holiday periods verified that the SWD symptoms decreased during holidays. Appendix T5 presents the results of the comparisons of the SWD and reference groups.

Statistical analyses

We used IBM SPSS Statistics 25.0 (IBM Corp., Armonk, NY, USA) and SAS 9.4 (SAS Institute Inc., Cary, North Carolina, USA) for the statistical analyses. We used the paired samples *t-test* to verify whether the length and timing of sleep differed during work shifts and on days off in the SWD group (Appendix T2–3). We used the Wilcoxon signed-ranks test to explore whether the occurrence of SWD symptoms during the shift work and holiday periods differed in the SWD and reference groups (Appendix T5). To compare the groups, we applied the independent samples *t-test*, the Mann–Whitney *U-test*, or Fisher's exact test, depending on the scale and distribution of each variable. We applied the Wilcoxon signed-ranks test to compare the sleep length and sleep debt on workdays and days off, workdays and holidays, and days off and holidays of the SWD and reference groups. Exact and repeated logistic regression models were used to adjust the analyses for age or chronotype. However, the results of the chronotype-adjusted analyses are not shown, because they were similar to the results of the unadjusted and age-adjusted analyses.

Results

Sample characteristics

Table 1 presents the characteristics of the SWD (n=21, 76% men) and reference (n=9, 78% men) groups. The SWD group was on average seven yrs (95% CI -14, 0) younger than the reference group (p=0.043). The SWD group had a longer subjective sleep need than the reference group (U=48.5, p=0.030). The groups were comparable in terms of sex, chronotype, shift work experience, objective 24-hour total sleep time, work shifts, and having treated obstructive sleep apnoea.

Table 2. Self-estimated sleep length among those with SWD (n=21) and those in reference group (n=9)

Sleep length during last two weeks	SWD		Reference		p [a]
	Median	(Q_1, Q_3)	Median	(Q_1, Q_3)	
Workdays (h) [b]	6.3	(6.0, 7.0)	7.0	(7.0, 7.8)	0.003
Days off (h) [b]	8.0	(7.0, 8.5)	7.5	(7.0, 8.5)	0.744
Holidays (h) [c]	8.0	(7.4, 8.5)	8.5	(7.8, 9.0)	0.238

Q_1 1st quartile; Q_3, 3rd quartile

[a] Mann–Whitney *U-test*

[b] Response during work period

[c] Response after at least two weeks of being on holiday

Self-estimated sleep length

Table 2 presents the sleep length of the study groups. Compared to that of the reference group, those with SWD reported significantly shorter sleep on workdays (U=32.5, p=0.003), but not on days off or during holidays, as indicated by the Mann–Whitney *U-tests*. The age-adjusted exact logistic regression analyses indicated similar results (workdays: OR 0.12, 95% CI 0.01–0.64, p=0.007).

The Wilcoxon signed-ranks tests indicated significantly shorter sleep on workdays than on days off among those with SWD (Z=−3.97, p<0.001), but not among those in the reference group (Z=−1.76, p=0.078). Sleep was also significantly shorter on workdays than during holidays among those with SWD (Z=−4.05, p<0.001) and among those in the reference group (Z=−2.39, p=0.017). Sleep length did not significantly differ on days off and during holidays among those with SWD (Z=−1.17, p=0.242) or among those in the reference group (Z=−1.89, p=0.058). Apart from an analysis of workdays and days off which was inconclusive, age-adjusted repeated logistic regression analyses indicated similar results (workdays and holidays: OR −0.00, 95% CI −0.00–−0.00, p=0.007; days off and holidays: p=0.568) to the Wilcoxon signed-ranks tests.

Sleep debt

Fig. 2 presents the sleep debt of the groups. Those with SWD had a significantly greater sleep debt on workdays (U=15.5, p<0.001), days off (U=50.5, p=0.040), and during holidays (U=42.0, p=0.016) than those in the reference group, as indicated by the Mann–Whitney *U-tests*. Age-adjusted exact logistic regression analyses indicated that SWD was positively associated with sleep debt on workdays (OR 9.29, 95% CI 1.83–202.20, p<0.001) and during holidays (OR 2.41, 95% CI 1.14–6.58, p=0.018), but not on days off.

Recovery

Those with SWD experienced good recovery from irregular working hours less often (14%, n=3/21) than those in the reference group (100%, n=9/9; p<0.001, Fig. 3). This was supported by an age-adjusted exact logistic regression analysis (OR 0.02, 95% CI 0.00–0.11, p<0.0001).

Discussion

We studied recovery during holidays in SWD utilising questionnaire responses on sleep length during work and holiday periods. This is the first study to investigate the amount of sleep or sleep debt in SWD cases during a naturalistic shift work washout period. Holidays were associated with longer sleep estimates than workdays among shift workers both with and without SWD. Whereas the employees without SWD reported longer sleep than sleep need during holidays, the employees with SWD estimated having similar sleep length and sleep need. This, together with sleep debt and suboptimal recovery from irregular working hours among the shift workers with SWD, suggests that the recovery of those with SWD is compromised.

As we expected, the employees both with and without SWD estimated that they slept longer during holidays than on workdays. Although longer sleep need has been associated with SWD[17] and dissatisfaction with shift work[30], those with SWD did not report longer sleep during holidays than those without SWD. Contrary to our hypothesis, the employees with SWD estimated that they slept approximately the same amount during holidays as their perceived sleep need (i.e., they had zero hours of sleep debt), whereas those without SWD estimated that they slept more. Future studies could explore whether leaving shift work would diminish the group difference if, for example, the perceived sleep need in the different groups changed in different ways.

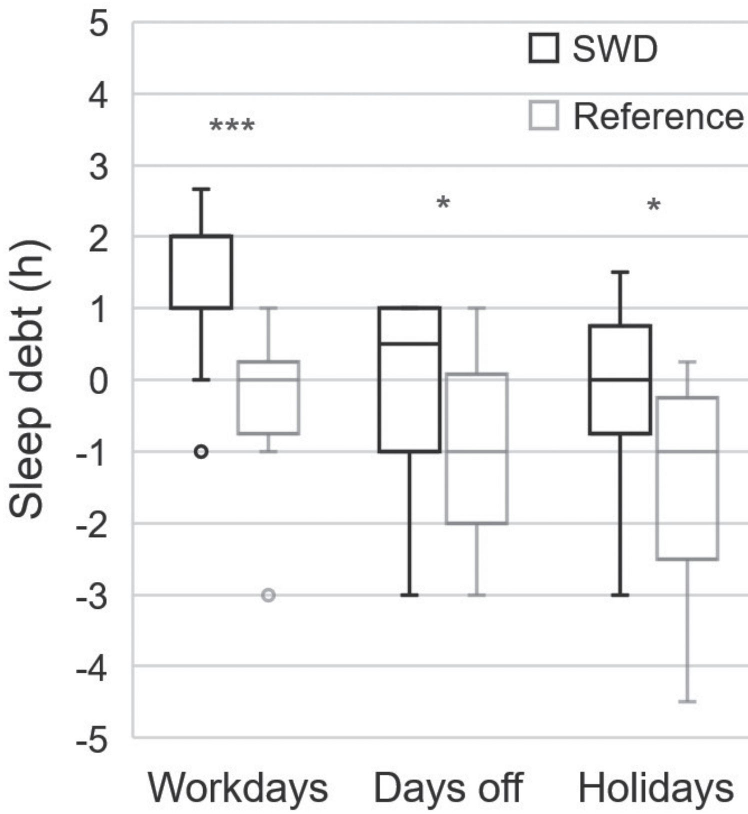

Fig. 2. Box-and-whisker plot of sleep debt.
○ = outlier. SWD (black), Reference (grey). Mann–Whitney *U-test:* * = *p*<0.05, * = *p*<0.001**

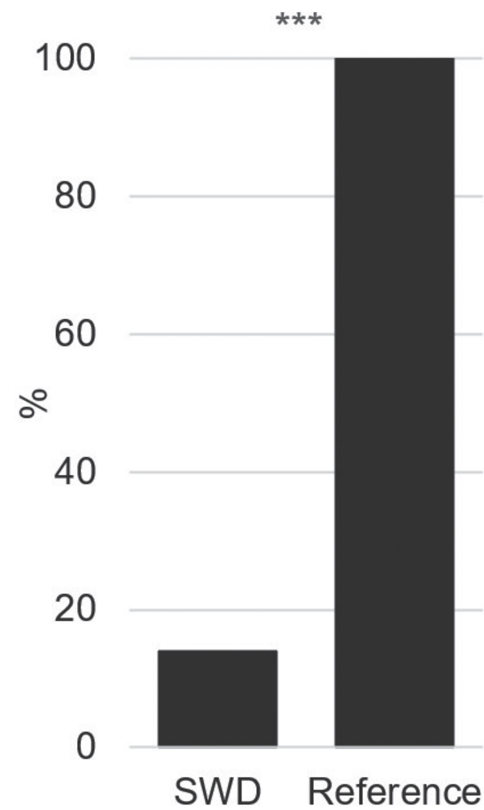

Fig. 3. Percentage of shift workers with good recovery from irregular working hours.
Fisher's exact test: * = *p*<0.001**

All the shift workers without SWD recovered well from irregular working hours, while the employees with SWD reported mainly suboptimal recovery. This is in line with studies that have associated the manifestation of SWD on workdays with shorter subjective sleep[17–19] and insufficient sleep[31]. Compared to workdays, the employees with SWD estimated their sleep length as longer on days that were not workdays, but they still showed sleep debt on days off. Those without SWD estimated that they slept longer on days off than their subjective sleep need. Thus, in addition to recovery sleep, the reference group members' sleep might also be prophylactic, counteracting the negative effects of shift work on workdays following days off[32]. Those with SWD might lack this kind of prophylactic sleep. Indeed, objective 24-hour sleep was close to the reference cases' subjective sleep need, which is in line with a recent study of truck drivers[33], whereas those with SWD slept over an hour less than their sleep need when not on holiday.

This is the first study of SWD to evaluate sleep length in relation to holidays and to compare responses after a real-life shift work washout period with responses during a work period. As SWD symptoms should be associated with a shift work schedule[15], and not with a long recovery period, we considered severe symptoms during holidays as being unrelated to SWD. This probably prevented us from confusing SWD with conditions of continuing insomnia and/or sleepiness. However, as SWD and other disorders can occur simultaneously, the participants of the current study could have one holiday-related insomnia/sleepiness symptom, provided that the separate symptom that defined a person as an SWD case did not occur during holidays in the SS-Q. The work- and holiday-related questionnaire responses of those with SWD verified that the subjective frequency of the symptoms of insomnia and sleepiness did indeed decrease in relation to a real holiday. We also verified disturbed sleep-wake patterns and reduced total sleep time among those with questionnaire-based SWD using sleep diaries and actigraphy, as required by the ICSD-3 criteria.

The current study has limitations, such as its usage of subjective measures and variables averaged over two weeks. Thus, probable daily variation of sleep need and sleep debt in longer recovery from SWD remains to be studied. We used a subjective measure of sleep need, which can provide inaccurate or overly short estimations of actual sleep need. On the other hand, objective assessment of sleep need may not be feasible in an observative field setting if full recovery takes longer than the recovery periods available in a shift work schedule. In addition, in real life, habitual sleep (that has been used as an estimate for sleep need) can be shorter than actual sleep need, even if individuals are not shift workers[34, 35]. Nevertheless, studies that use objective measures of sleep need, such as sleep restriction or sleep extension protocols, are required to confirm our results concerning sleep need. Furthermore, although the ICSD-3 states that SWD symptoms should manifest for at least three months, the SS-Q did not specify the manifestation period; it focused on generic symptoms in connection with different shift types. In addition, to simplify the interpretation of the results, we excluded shift workers with milder SWD symptoms whom we could not classify as either clear SWD cases or clear non-SWD cases. This added a contrast between the groups. Statistical power was limited because of small the sample size, but it was adequate for observing significant differences between the groups. Further, younger age has been related to longer and better sleep[36] and lesser need for recovery[37] than older age, and in our study, the shift workers with SWD were younger than those without SWD, which may have diminished the differences between the groups. The younger age of the employees with SWD may have partially resulted from the healthy worker effect[38], since those with SWD are possibly at a higher risk of leaving shift work.

To conclude, holidays increased the amount of self-estimated sleep, regardless of SWD status. However, the employees with SWD appeared to have a consistently longer sleep debt than those without SWD, which partially resulted from the greater sleep need among those with SWD. Moreover, the shift workers with SWD reported primarily suboptimal recovery from irregular working hours, unlike those without SWD, who all recovered well. All the above support the notion of less efficient recovery among shift workers with SWD. Future studies could examine whether shift workers with SWD would benefit from extended recovery periods in their roster or from individualised rota planning.

Conflict of Interest

CH reports outside the present work a grant from Finska Läkaresällskapet and from the Finnish Work Environment Fund, and personal fees from the National Institute of Health and Welfare and the Orion Corporation. The other authors have no conflict of interest.

Acknowledgements

We thank Paula Niemelä for recruiting the participants and for making the practical arrangements, and Alice Lehtinen (Altexta) for the language editing of this article. The study was funded by the Finnish Work Environment Fund (111102) and NordForsk (74809).

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