Received: 8 March 2018 | Revised: 8 April 2019 | Accepted: 10 April 2019

DOI: 10.1002/1348-9585.12063

ORIGINAL ARTICLE

Journal of Occupational Health Open Access WILEY

The effects of a 120-minute nap on sleepiness, fatigue, and performance during 16-hour night shifts: A pilot study

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Funding information
Japan Society for the Promotion of Science, Grant/Award Number: JP26293452; Ministry of Education, Culture, Sports, Science and Technology, Grant/Award Number: JP22390409

Abstract

Objective: To investigate sleepiness, fatigue, and performance following a 120-minute nap during simulated 16-hour night shifts based on subjective and objective assessments.

Methods: Fourteen females participated in this crossover comparative study. Three experimental nap conditions were used: naps from 22:00 to 00:00 (22-NAP), 00:00 to 02:00 (00-NAP), and 02:00 to 04:00 (02-NAP), respectively. Measurement items were sleep parameters, sublingual temperature, a Visual Analog Scale for sleepiness and fatigue, a single-digit mental arithmetic task (for 10 minutes), and heart rate variability. Participants wore an ActiGraph to estimate their sleep state.

Results: There was no difference in the sleep parameters at the time of naps among the three conditions. Immediately following a 120-minute nap, sleepiness and fatigue increased, and the number of calculations performed in the single-digit mental arithmetic task decreased in any of the conditions. In particular, immediately after the 02-NAP, fatigue and high-frequency power (HF) were higher than after the 22-NAP. In the early morning (from 05:00 to 09:00), in the 22-NAP, sleepiness and fatigue increased, and performance and sublingual temperature decreased more than in the 00-NAP and 02-NAP. Furthermore, the ratio of errors was significantly lower in the 00-NAP than in the 22-NAP in the early morning.

Conclusions: A 120-minute nap taken from 22:00 to 02:00 may cause temporary sleepiness after waking, increase fatigue and reduce performance. Greater attention should be given to naps taken at a later time (ie, 02-NAP). In addition, taking a nap starting at 00:00 might decrease the risks of errors in the morning.

KEYWORDS
fatigue, nurse, occupational stress, shift work schedule, wakefulness

1 | INTRODUCTION

Japan is increasingly becoming a society that works around the clock.[1] As a result, rotating shifts involve the adoption of nighttime work, leading to shift work becoming an essential pattern in different service sectors. Shift work presents a threat to workers' health, making them more prone to various health problems compared to regular dayshift workers; nevertheless, the number of shift workers has increased over time in Japan.[2]

The medical profession, especially nursing, is a typical example of an industry that has adopted a shift work system. In Japan, many nurses work on two- or three-shift systems. In two-shift systems, there are two major forms of night shifts: 12-hour shifts and 16-hour shifts. In particular, 16-hour night shifts are a burden for nurses both physically and mentally. Previous research has indicated that nurses on such schedules are troubled by morning sleepiness and fatigue,[3,4] which can increase the risk of traffic accidents after work.[5]

There is an interest in the effects of taking a nap during the night shift as a means of recovering from night shift fatigue. A previous study showed that not napping during the night shift decreased performance from 06:00 to 09:00.[6] Several studies have indicated that napping can reduce sleepiness and maintain the efficiency of workers.[7,8] Informally, nursing staff at public hospitals are usually allowed to sleep or rest for up to 2 hours during 16-hour night shifts[9] and many nurses nap during the night shift.[10] It is common for nurses to nap between 22:00 and 06:00.[11] A nap during the night shift that allows sleep from slow-wave to rapid eye movement sleep in the same way as normal nighttime sleep seems to be effective and has been recommended.[12] However, the effects of napping differ depending on the duration and starting time of the nap.[13] With 60-minute naps, there is a problem with residual sleepiness due to sleep inertia. Sleep inertia refers to the brief period of reduced alertness and impaired cognitive performance experienced immediately after waking.[14] To minimize sleep inertia, napping for 90–110 minutes in one cycle is considered appropriate.[15] Also, a 120-minute nap sustained early morning performance better than a 60-minute nap.[16] However, no previous studies have clarified the effects of a 120-minute nap on sleepiness, fatigue, performance, and sleep inertia in simulated 16-hour night shifts.

Therefore, the purpose of this study was to investigate performance, sleepiness, fatigue, and physiological measures immediately after napping and in the early morning period following a 120-minute nap during simulated 16-hour night shifts based on subjective and objective assessments. We hypothesized that under the conditions of biological night and extended wakefulness, a 120-minute nighttime nap would not lead to sleep inertia regardless of the starting time of the nap.

2 | METHODS

2.1 | Sample and data collection

Fourteen female college students were enrolled in this study. The mean age (±SD) of the 14 participants analyzed was 21.7 ± 0.9 years. None of the participants were obvious morning type or evening type on the "Morningness-Eveningness Questionnaire".[17] They had no previous night shift experience, and the study took place from August to November in 2012. Participants were non-smokers, non-obese (body mass index ≤ 25), and consumed low amounts of coffee and alcohol. They had normal sleep patterns (habitual sleep ranged between 7 and 9 hours), and were not under medication.

Data collection began 2 days before the experiment, with an ActiGraph (Ambulatory Monitoring Inc, Ardsley, USA) worn on the wrist and a diary to record activity and sleep. Furthermore, we asked the participants not to consume alcohol or caffeine, particularly coffee, during the study beginning on the day of the experiment. The participants conducted the same experiment three times, each of which included a 120-minute nap at different times. For each experiment, participants were randomly assigned to one of the three nap conditions using counterbalancing. The participants in the study were provided remuneration equivalent to the wages for one night shift.

This study was approved by the Ethics Committee for Epidemiologic Research at Okayama University Graduate School of Health Sciences, Japan. All participants provided informed consent prior to study involvement.

2.2 | Study design

Participants resided in a windowless and sound-insulated sleep laboratory for 2 consecutive days (1 night). The laboratory environment was set to a room temperature of 26±2°C,[18] humidity of 50%, and illumination of 200 lx. For naps, the participants moved to a room used specifically for napping and adjusted the temperature and lighting according to their own preferences. Participants wore loose-fitting, 100% cotton pajamas during napping.

A timeline diagram of the study design is shown in Figure 1. The measurements for one experiment were conducted over 2 consecutive days, between 16:00 and 09:00. The three conditions were 120-minute naps from 22:00 to 00:00 (22-NAP), 00:00 to 02:00 (00-NAP), and 02:00 to 04:00 (02-NAP). At the start of each experiment, the participants were fitted with an Active Tracer AC-301 (GMS Inc, Tokyo, Japan) and an ActiGraph. For each hour throughout the experiment, 20 minutes was measurement time in which the participants recorded their body temperature once, completed a Visual Analog Scale (VAS) on sleepiness and fatigue for 10 minutes, and were asked to perform a single-figure mental arithmetic task for 10 minutes. The next 20 minutes were free time, and the remaining 20 minutes were rest time. The participants spent their free time drinking water, reading, or drawing. The 20 minutes of rest time were spent sitting on chairs or chatting with other participants. The same amount and contents of meals were given to the participants at 19:20-19:40 in each experimental period. The Active Tracer AC-301 was removed at the end of the experiment, but the participants were requested to keep wearing the ActiGraph unit until they woke up the following day. At the end of each scheduled nap time, the researcher notified the participants that it was time to wake up. There was an interval of 1 month between experiments.

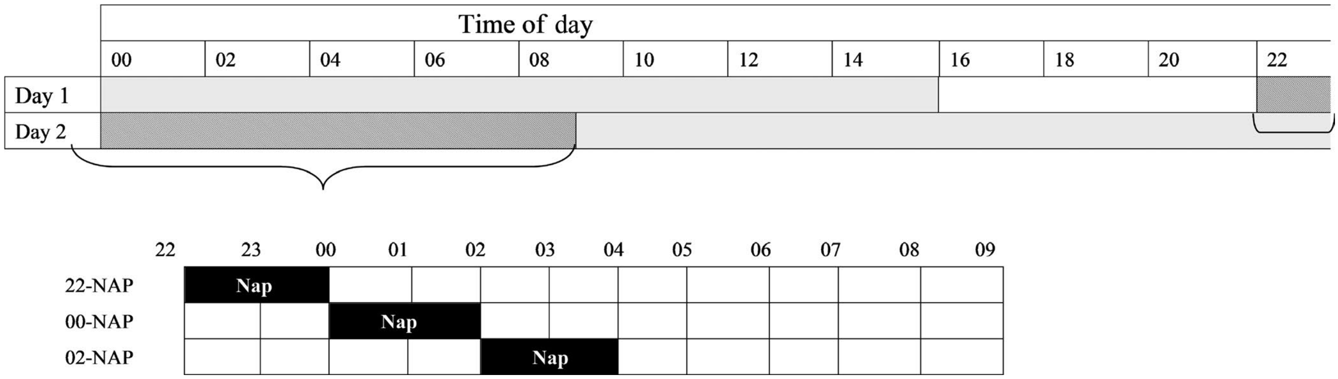

FIGURE 1 Schematic of the study protocol. Each row represents 24 h. The black areas indicate nap times. The diagonal hatching shows all three conditions during that time period

2.3 | Measurements

2.3.1 | Sleep parameters

Measured sleep parameters included total sleep time (TST), sleep efficiency (SE; TST/time in bed *100), sleep onset latency (SOL), wake after sleep onset (WASO) and all were measured with the ActiGraph. The data were analyzed using the software package AW2 (Ambulatory Monitoring Inc).

2.3.2 | Autonomic nervous system activity

Reproducibility of heart rate variability (HRV) is sleep-stage dependent. It can satisfactorily be detected based on R-R intervals derived from electrocardiography (ECG) recordings, without the need of full polysomnography (PSG).[19] In this study, HRV was obtained through autoregressive analysis of the R-R intervals measured from 16:00 to 09:00. Data were analyzed offline after analog-to-digital conversion of 250-Hz R-R waves. HRV, measured every 5 minutes for each hour and then averaged, was included to monitor autonomic nervous system activity throughout the night.[20] HF is generally employed as an indicator of cardiac parasympathetic nervous activity, and the low-frequency power/high-frequency power ratio (LF/HF) as an indicator of cardiac sympathetic nervous activity.[21,22]

2.3.3 | Neurobehavioral parameters

The sleep effect battery included the following objective tasks and subjective scales, in order of presentation: a single-digit mental arithmetic task, sleepiness and fatigue assessment, and physiological measures.

Single-digit mental arithmetic task

Unless napping, participants performed a single-digit mental arithmetic task for 10 minutes every hour. The number of calculations carried out in 10 minutes was considered to be the participant's workload at that time.

Sleepiness and fatigue assessment

Sleepiness and fatigue were assessed subjectively using a VAS.[23] Participants rated their sleepiness and fatigue on a 100-mm line every hour except when they were napping. The values ranged from 0 mm (not at all sleepy or tired) to 100 mm (extremely sleepy or tired).

2.3.4 | Physiological parameters: sublingual temperature

The circadian rhythm of body temperature is one of the most common indicators of circadian rhythmicity,[24] and body temperature is an indicator related to sleepiness, fatigue, and performance in a single-digit mental arithmetic task.[25] Sublingual temperature was measured as an index of internal body temperature.[26] Using an oral thermometer (MC-612; Omron Inc, Kyoto, Japan), sublingual temperature was measured hourly to examine changes in circadian modulation during the night.

2.4 | Statistical analysis

Sleep variables during the naps were analyzed using one-way ANOVA with a between-subjects fixed effect of condition.

In order to test the effects of a nap on neurobehavioral and physiological outcomes during the sleep inertia and early morning measurement periods, a fully saturated, linear mixed-effects ANOVA[27] with a between-subjects fixed effect of condition (22-NAP, 00-NAP, 02-NAP) and a within-participant fixed effect of time (at 20:00 or 21:00 vs before and after napping; at 20:00 or 21:00 vs from 05:00 to 09:00) and random intercept were used. Within-condition comparisons were chosen in order to minimize the influence of individual differences. As a secondary analysis, between-condition comparisons were also assessed for each time.

To evaluate the patterns of change in all three nap conditions, multiple comparisons were assessed using the Bonferroni correction. Statistical analyses were performed using IBM SPSS statistics software version 22.0J (IBM, Tokyo,

TABLE 1 Sleep variables in this study

Variable	22-NAP	00-NAP	02-NAP	*F* (2, 39)	*P*-value
TST (min)	93.4 (31.5)	103.9 (8.2)	103.8 (12.6)	1.247	0.298
SOL (min)	14.3 (22.1)	9.1 (9.5)	8.5 (9.2)	0.633	0.539
WASO (min)	5.4 (13.4)	1.0 (2.4)	1.7 (5.2)	1.222	0.312
SE (%)	95.3 (11.4)	99.1 (2.2)	98.1 (5.5)	0.991	0.381
HF	720.3 (623.8)	855.0 (889.2)	1318.9 (1612.6)	1.096	0.344
LF/HF	2.0 (2.0)	1.7 (1.4)	2.2 (2.9)	0.176	0.839

Note: Data are mean (SD). The 22-NAP was a nap at 22:00-00:00, the 00-NAP was a nap at 00:00-02:00 and the 02-NAP was a nap at 02:00-04:00.
TST, WASO, and SE were measured by ActiGraph during naps.
HF and LF/HF were measured by the Active Tracer.
HF, high frequency; LF, low frequency; SE, sleep efficiency; SOL, sleep onset latency; TST, total sleep time; WASO, wake after sleep onset.

Japan). The hypothesis rejection level for all tests was set at a *P*-value of <0.05.

3 | RESULTS

3.1 | Sleep state before and during the experiment

The mean wake-up time on the experiment days was 09:04 ± 01:02 in the 22-NAP, 08:58 ± 01:23 in the 00-NAP, and 08:42 ± 00:58 in the 02-NAP, with no significant difference among the three conditions.

No significant differences were observed among TST, SOL, WASO, SE, and autonomic nervous system activity (ie, HF and LF/HF) for any of the three nap conditions when naps were taken on various days (Table 1). However, among the 14 participants included in the analysis, three participants in the 22-NAP and two participants in the 02-NAP could not sleep, and their SOL as measured by the ActiGraph was over 30 minutes.

3.2 | Impacts immediately before and after a 120-minute nap

3.2.1 | Autonomic nervous system activity

High-frequency power showed a significant main effect of condition (Figure 2A; Table 2). HF after the 02-NAP was significantly higher than after the 22-NAP. Also, LF/HF showed a significant main effect of time (Figure 2B). LF/HF before and after the nap was significantly lower than at 20:00 in all nap conditions.

3.2.2 | Neurobehavioral parameters

Figure 2C shows the number of calculations performed immediately before and after a 120-minute nap. There was a significant main effect of time for the number of calculations such that the number of calculations performed immediately after a nap was significantly lower than before the nap at 21:00. The ratio of errors had no significant main or interaction effects (Figure 2D).

Figure 2E shows the scores for sleepiness. There was a significant main effect of time. Sleepiness immediately after a nap was significantly greater than before the nap at 21:00. For fatigue (Figure 2F), there was a significant main effect of condition and time. After the 02-NAP, fatigue was significantly greater than after the 22-NAP. Similar to sleepiness, fatigue immediately after a nap was significantly higher than before the nap at 21:00.

3.2.3 | Physiological parameters

For temperature, there was a significant main effect of time such that temperature before and after all nap conditions was significantly lower than at 21:00 (Figure 2G).

3.3 | Influence of a 120-minute nap early in the morning

3.3.1 | Autonomic nervous system activity

High-frequency power showed a significant main effect of time (Figure 3A; Table 3). HF from 05:00 to 09:00 was significantly higher than at 21:00. LF/HF showed a significant main effect of condition (Figure 3B). After the 02-NAP, LF/HF was significantly higher than after the 00-NAP.

3.3.2 | Neurobehavioral parameters

Figure 3C shows the number of calculations performed from 05:00 to 09:00 compared to at 20:00. There was a significant main effect of condition and time (Table 3). The number of calculations performed after the 22-NAP was significantly lower than after the 00-NAP and 02-NAP. Furthermore, the number of calculations performed at 05:00 to 09:00 was lower than at 20:00. The ratio of errors was recognized as having a significant main effect of condition and time (Figure 3D), with the ratio of errors

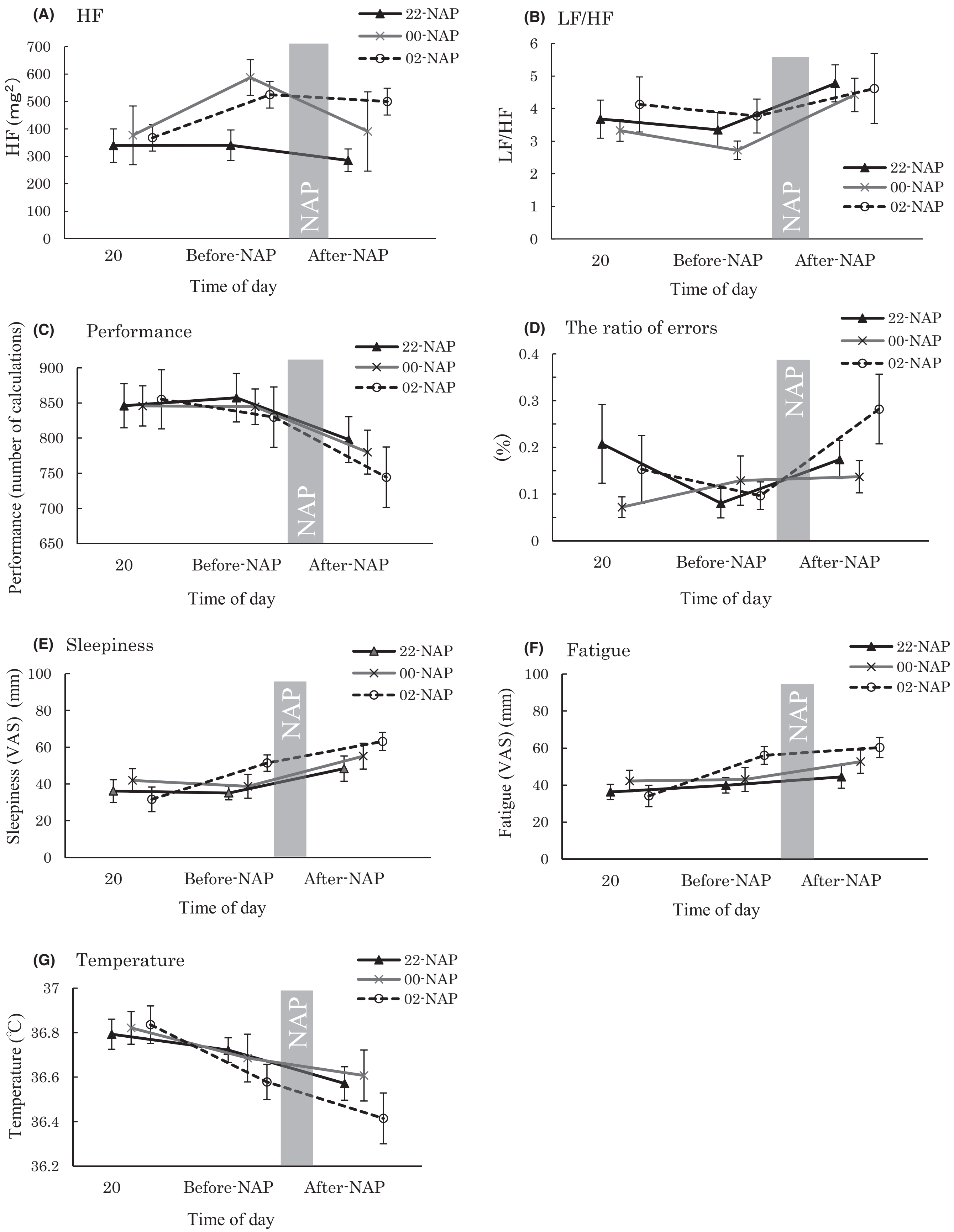
(A) HF
22-NAP
00-NAP
02-NAP
HF (mg²)
700
600
500
400
300
200
100
0
NAP
20
Before-NAP
After-NAP
Time of day
(B) LF/HF
LF/HF
6
5
4
3
2
1
0
NAP
22-NAP
00-NAP
02-NAP
20
Before-NAP
After-NAP
Time of day
(C) Performance
22-NAP
00-NAP
02-NAP
Performance (number of calculations)
900
850
800
750
700
650
NAP
20
Before-NAP
After-NAP
Time of day
(D) The ratio of errors
22-NAP
00-NAP
02-NAP
(%)
0.4
0.3
0.2
0.1
0
NAP
20
Before-NAP
After-NAP
Time of day
(E) Sleepiness
22-NAP
00-NAP
02-NAP
Sleepiness (VAS) (mm)
100
80
60
40
20
0
NAP
20
Before-NAP
After-NAP
Time of day
(F) Fatigue
22-NAP
00-NAP
02-NAP
Fatigue (VAS) (mm)
100
80
60
40
20
0
NAP
20
Before-NAP
After-NAP
Time of day
(G) Temperature
22-NAP
00-NAP
02-NAP
Temperature (℃)
37
36.8
36.6
36.4
36.2
NAP
20
Before-NAP
After-NAP
Time of day

FIGURE 2 Mean (±SEM) at 20:00 or 21:00 versus before and after napping, for (A) HF, (B) LF/HF, (C) performance (number of single-digit calculations performed), (D) the ratio of errors, subjective (E) sleepiness and (F) fatigue and (G) temperature (sublingual). HF, high-frequency power; LF, low-frequency power

after the 22-NAP being significantly higher than after the 00-NAP. Furthermore, the ratio of errors at 08:00 was significantly higher than at 20:00.

Figure 3E and 3 shows the scores for sleepiness and fatigue. From 05:00 to 09:00, compared to at 21:00, there was a significant main effect of condition and time. After the 22-NAP, sleepiness and fatigue were significantly increased compared to after the 00-NAP and 02-NAP. Furthermore, sleepiness and fatigue from 05:00 to 09:00 were significantly higher than at 21:00.

3.3.3 | Physiological parameters

Figure 3G shows the sublingual temperature at 21:00 and from 05:00 to 09:00. Compared to at 21:00, sublingual temperature from 05:00 to 09:00 showed a significant main effect of condition and time. After the 22-NAP, sublingual temperature was significantly lower than after the 00-NAP and the 02-NAP. Furthermore, sublingual temperature from 05:00 to 09:00 was significantly lower than at 21:00.

4 | DISCUSSION

4.1 | Sleep parameters

Sleep parameters, including TST, SE, SOL, and WASO, were adopted and measured with the ActiGraph. The ActiGraph results indicated that there were no differences in TST during naps, SOL or SE among the three nap conditions. The wake-up time, sleep latency after nighttime sleep and SE of the present participants were similar to the wake-up time (08:18), sleep latency (10.1 minutes) after nighttime sleep and SE (94.1%) of ordinary college students.[28]

Examining the autonomic nervous system during napping revealed that HF, which is used as an indicator of parasympathetic nervous activity, showed no difference among the three nap conditions. Similarly, LF/HF, which is used as an indicator of sympathetic nervous activity,[29] showed no difference among the three nap conditions tested in the present study. Therefore, we assumed that the starting time of the nap did not affect sleep latency, SE or autonomic nervous activity.

4.2 | Impacts immediately after napping

One of the major demerits of napping is increased sleepiness after waking. In this study, the number of calculations performed by the participants after napping decreased; however, the ratio of errors just after waking from sleep was not significantly different from before napping.

The strength of sleepiness is affected substantially if the body temperature rhythm reaches its lowest point during sleep or if the period of alertness is long before going to sleep.[30] In this study, the nap duration was set to 120 minutes

TABLE 2 Results from the linear mixed-effects analysis of variance for neurobehavioral and physiological outcomes at 20:00 or 21:00 versus before and after napping

Variable	*df*	*F*	*P*-value
HF			
Condition	2, 104	3.777	0.026
Time	2, 104	0.258	0.773
Condition × time	4, 104	0.756	0.556
LF/HF			
Condition	2, 104	2.025	0.137
Time	2, 104	23.843	<0.001
Condition × time	4, 104	0.138	0.968
Performance			
Condition	2, 104	0.709	0.495
Time	2, 104	8.207	<0.001
Condition × time	4, 104	0.422	0.793
Ratio of errors			
Condition	2, 104	1.486	0.231
Time	2, 104	2.230	0.113
Condition × time	4, 104	1.421	0.232
Sleepiness			
Condition	2, 104	2.087	0.129
Time	2, 104	10.084	<0.001
Condition × time	4, 104	1.651	0.167
Fatigue			
Condition	2, 104	3.418	0.036
Time	2, 104	7.720	0.001
Condition × time	4, 104	1.803	0.134
Temperature			
Condition	2, 104	2.416	0.094
Time	2, 104	17.962	<0.001
Condition × time	4, 104	1.211	0.311

Note:: Performance, number of single-digit mental arithmetic calculations performed; Ratio of errors, number of total errors/total number of calculations performed; Sleepiness and fatigue, rated on a Visual Analog Scale; Temperature, sublingual temperature; HF, high-frequency power; LF/HF, low-frequency power/high-frequency power ratio.
Significant effect at $P < 0.05$.

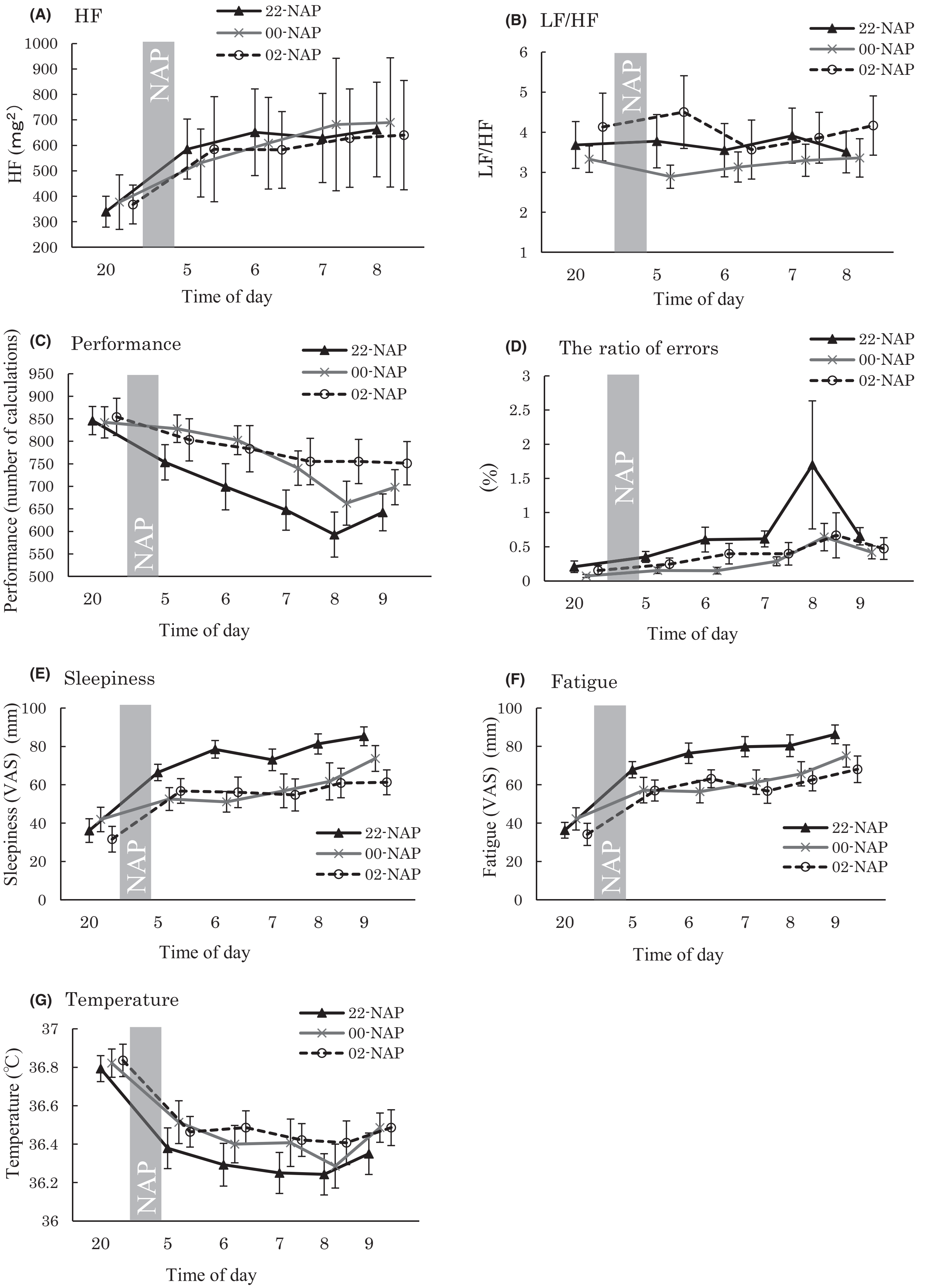
(A) HF
22-NAP
00-NAP
02-NAP
NAP
HF (mg²)
1000
900
800
700
600
500
400
300
200
20
5
6
7
8
Time of day
(B) LF/HF
22-NAP
00-NAP
02-NAP
NAP
LF/HF
6
5
4
3
2
1
20
5
6
7
8
Time of day
(C) Performance
22-NAP
00-NAP
02-NAP
NAP
Performance (number of calculations)
950
900
850
800
750
700
650
600
550
500
20
5
6
7
8
9
Time of day
(D) The ratio of errors
22-NAP
00-NAP
02-NAP
NAP
(%)
3
2.5
2
1.5
1
0.5
0
20
5
6
7
8
9
Time of day
(E) Sleepiness
22-NAP
00-NAP
02-NAP
NAP
Sleepiness (VAS) (mm)
100
80
60
40
20
0
20
5
6
7
8
9
Time of day
(F) Fatigue
22-NAP
00-NAP
02-NAP
NAP
Fatigue (VAS) (mm)
100
80
60
40
20
0
20
5
6
7
8
9
Time of day
(G) Temperature
22-NAP
00-NAP
02-NAP
NAP
Temperature (℃)
37
36.8
36.6
36.4
36.2
36
20
5
6
7
8
9
Time of day

FIGURE 3 Mean (±SEM) at 20:00 or 21:00 versus from 05:00 to 09:00, for (A) HF, (B) LF/HF, (C) performance (number of single-digit calculations performed), (D) the ratio of errors, subjective (E) sleepiness and (F) fatigue, and (G) temperature (sublingual). HF, high-frequency power; LF, low-frequency power

for all three nap conditions and the sleep state was same in all three conditions.

In all three nap conditions, immediately after napping, sleepiness and fatigue were increased and the number of calculations performed was lower than at 20:00 or 21:00. Changes in body temperature and performance are consistent,[31] meaning that performance decreases as body temperature decreases. In the present study, after the 02-NAP, fatigue and HF were significantly higher than after the 22-NAP. These results suggest that when taking a 120-minute nap after 02:00, fatigue temporarily increases and parasympathetic activity increases after waking from sleep.

4.3 | Early morning period

Changes in body temperature follow a circadian rhythm and are used to assess physiological performance.[32] Dawson et al[33] investigated fatigue and work efficiency when remaining awake for 28 hours from 08:00 to 12:00 the following day. They found a drop in work efficiency from 00:00 to 07:00 with a prolonged period of alertness, suggesting that lack of sleep at night increases the risk of accidents.[33] In the present study, after the 22-NAP, body temperature was significantly lower than after the 00-NAP or 02-NAP. In particular, since the ratio of errors was significantly lower than after the 22-NAP, the 00-NAP seems to be effective in reducing the risk of error. Since there is a correlation between decreased body temperature and increased sleepiness,[34,35] changes in body temperature suggested that the 22-NAP was responsible for greater sleepiness than the 00-NAP or 02-NAP.

After the 22-NAP, HF and fatigue increased, and LF/HF decreased compared to the 00-NAP or 02-NAP. As a result, if a 120-minute nap was introduced from 22:00 to 04:00, starting the nap at 00:00 would be most effective in reducing sleepiness, fatigue, and risk of error in the early morning.

4.4 | Potential for utilization in nursing work sites

Based on the results of this study, during night work (eg, 16:00 to 09:00), a nap from 00:00 to 02:00 is thought to be effective in cases when tasks requiring quick responses to maintain a high level of safety are scheduled between 02:00 and 09:00. During this time period, circadian alertness is low[36] and the risk of accidents is increased. Therefore, a greater effect on the level of safety can be expected with the 00-NAP compared with the 22-NAP or 02-NAP.

4.5 | Limitations

This study was conducted under laboratory conditions. The degree of change in performance and sleepiness could vary from actual working conditions, which greatly depend upon differences in load due to the nature of the work or the timing of busy work periods. Intervention studies in

TABLE 3 Results from the linear mixed-effects analysis of variance for neurobehavioral and physiological outcomes at 20:00 or 21:00 versus from 05:00 to 09:00

Variable	*df*	*F*	*P*-value
HF			
Condition	2, 177	0.162	0.850
Time	4, 177	6.843	<0.001
Condition × time	8, 177	0.144	0.997
LF/HF			
Condition	2, 177	7.936	0.001
Time	4, 177	0.432	0.785
Condition × time	8, 177	0.612	0.767
Performance			
Condition	2, 221	13.176	<0.001
Time	5, 221	14.148	<0.001
Condition × time	10, 221	1.119	0.349
Ratio of errors			
Condition	2, 221	4.060	0.019
Time	5, 221	4.175	0.001
Condition × time	10, 221	0.658	0.762
Sleepiness			
Condition	2, 221	16.081	<0.001
Time	5, 221	16.420	<0.001
Condition × time	10, 221	1.335	0.213
Fatigue			
Condition	2, 221	18.798	<0.001
Time	5, 221	29.330	<0.001
Condition × time	10, 221	1.549	0.123
Temperature			
Condition	2, 221	7.698	0.001
Time	5, 221	26.456	<0.001
Condition × time	10, 221	0.447	0.922

Note:: Performance, number of single-digit mental arithmetic calculations performed; Ratio of errors, number of total errors/total number of calculations performed; Sleepiness and fatigue, Visual Analog Scale; Temperature, sublingual temperature; HF, high-frequency power; LF/HF, low-frequency power/high-frequency power ratio.
Significant effect at $P < 0.05$.

actual workplaces will need to be carried out to clarify effective measures for reducing sleepiness and fatigue that are tailored to the conditions of specific professions and workplaces. In previous studies, shift workers have been shown to have poorer quality and quantity of sleep,[37] a tendency for disrupted circadian rhythms, and many complain of fatigue compared with daytime workers. Moreover, the quality of sleep deteriorates with age,[38,39] and the quality of sleep among middle-aged people involved in night work is usually poorer than that of younger people. Therefore, it is possible that the present results differ from actual shift workers, and caution should be exercised when interpreting the results. The participants in this study were all women in their 20s with no shift work experience, and the experiment was performed with avoidance of the menstrual period. Since the menstrual cycle affects sleepiness,[40] this may have affected the results. This is an issue we would like to investigate further in the future.

5 | CONCLUSION

This is the first study to investigate performance, sleepiness, fatigue, and physiological measures following a 120-minute nap during simulated 16-hour night shifts based on subjective and objective assessments. It was suggested that a 120-minute nap at night (22:00–04:00) provides the same sleep state regardless of the start time.

In the 02-NAP, fatigue temporarily increased and parasympathetic activity increased after waking from sleep (ie, at 04:00). If a 120-minute nap is introduced from 22:00 to 04:00, starting the nap at 00:00 will be effective in reducing sleepiness, fatigue, and the risk of error in the early morning.

ACKNOWLEDGMENTS

We would like to thank all subjects who participated in the study. This work was supported by JSPS KAKENHI grant number JP22390409 and JP26293452.

DISCLOSURE

Approval of the research protocol: This study was implemented with the approval of the institutional review board of Okayama University Graduate School of Health Sciences (approval number: T11-02). *Informed consent*: Before providing written informed consent to participate in the study and prior to the study procedures being performed, all participants were provided with a sufficient explanation of voluntary withdrawal without penalty, and the protection of personal information. *Registry and the registration no. of the study/trial*: N/A *Animal studies*: N/A *Conflicts of interest*: N/A.

AUTHOR CONTRIBUTIONS

SO and YM conceived the ideas; SO collected and analyzed the data; and OS and MMR led the writing.

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How to cite this article: Oriyama S, Miyakoshi Y, Rahman MM. The effects of a 120-minute nap on sleepiness, fatigue, and performance during 16-hour night shifts: A pilot study. *J Occup Health*. 2019;61:368–377. https://doi.org/10.1002/1348-9585.12063