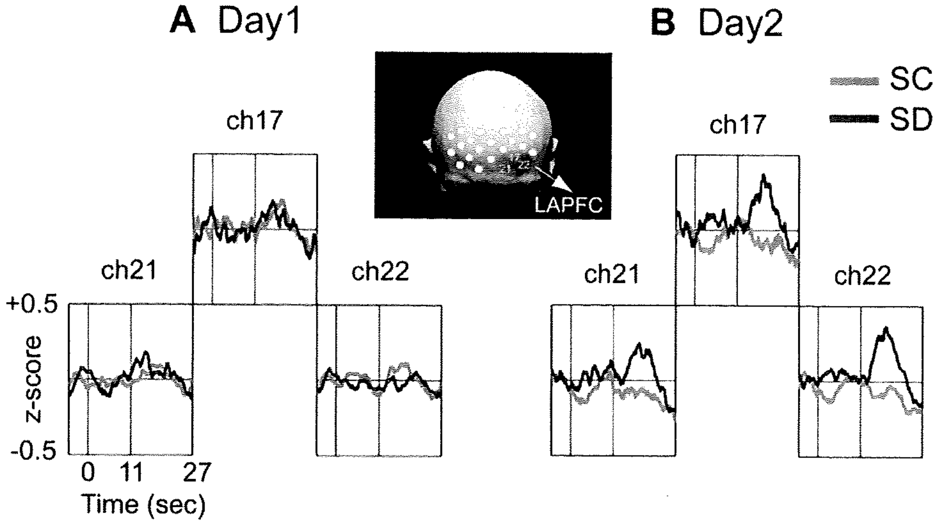

Figure 2. Time course of grand averaged oxygenated hemoglobin (oxy-Hb) concentration changes during 10-s time production trial in the left anterior prefrontal (LAPFC) (n = 14). Comparison of oxy-Hb concentration changes between the SC (green line) and the SD (red line) conditions on (A) day 1 and (B) day 2 in the LAPFC (chs.17, 21, 22). Scores of 0, 11 and 27 below the waveform box indicate the onset of the trial, the end of the trial, and the finish of the post-trial rest, respectively. Oxy-Hb changes are given as z-scores. Any significant differences in oxy-Hb concentration changes between the SC and the SD conditions in the right hemisphere except for in the left hemisphere are not observed on day 2. Marked differences in oxy-Hb concentration changes between conditions are observed in the LAPFC on day 2.
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control of the false discovery rate; FDR)]. Each channel in the ROI also showed a significant difference [ch.22: $t(1,13) = 3.066$, $p = 0.009$ ($p < 0.0125$: FDR); ch.17: $t(1,13) = 2.872$, $p = 0.013$ ($p < 0.025$: FDR)] or trend [ch.21: $t(1,13) = 2.007$, $p = 0.066$ ($p < 0.05$: FDR)]. A significant positive correlation was observed between produced time and change in oxy-Hb concentration in the overall ROI on day 2 in the SD condition [$r = 0.535$, $p = 0.049$; Fig. 3B].

Discussion

Sleep is believed to be a neural state during which both consolidation of memories and homeostatic preservations are taking place [41–44]. Sleep deprivation, even for the course of an extended active period of the day, eliminates these effects, and possibly results in a deterioration in cognitive activity [13,30,45].

The present study demonstrated that sleep deprivation modulates short-time perception behavior, as was suggested by earlier studies [27,30]. It has been shown previously that a short-time perception profile exhibits diurnal variation, reaching a peak (the longest produced time) around 09:00 and a nadir (the shortest produced time) around 21:00 with a regular sleep-wake cycle under experimental conditions [13]. Here, we measured produced time around both these expected peak and nadir periods in order to obtain approximate peak-to-peak amplitude of the diurnal variation of short-time perception. As a result, we found that the produced time at 09:00 was significantly attenuated after sleep deprivation compared with that after physiological sleep. It was unlikely that the alteration in properties of time perception after sleep deprivation was caused by circadian phase shifting (different peak times) of short-time perception rhythms between the SC and SD sessions because all participants were exposed to similar time cues such as dim light (<100 lux) and prohibited from physical exercise throughout the experiments, and the produced time levels around 21:00 were in fact identical between the two sessions. This seems to indicate that sleep deprivation per se modulated short-time perception. Given that produced time represents the rate of the biological stopwatch-like system [1], the attenuation of produced time observed on day 2 in the SD condition might be associated with the stopwatch-like system that runs faster [13].

A functional correlation of increased activation of the LAPFC after sleep deprivation with short-time perception behavior was observed in the present study, although unlike in previous studies, we failed to detect any significant changes in right PFC activity [8,9,14,15]. This discrepancy in the localized PFC activation findings between the present and previous studies is possibly attributable to experimental settings, tasks used and imaging modalities [9,14,24,46]. It has also been argued that increased activation of the PFC after sleep deprivation is associated with neural compensation for cognitive function [36,38,47], and the LAPFC activity observed in the present study should also be argued in the context of neural compensation: the LAPFC activity likely contributed to the third decision stage of temporal judgment in the three-stage model [9], with adaptive neural activity in the SD condition, although the produced time on day 2 in the SD condition was different from that in the SC condition.

It remains open as to whether or not a subcortical network including the cerebellum and the basal ganglia, assumed to be associated with timing processing, contributes to attenuating the diurnal fluctuation of short-time perception. Sustained wakefulness affects dopaminergic neuronal activity related with cognitive function as well as temporal function [48–50]. If alteration of subcortical activities might be caused by sleep deprivation, attenuation of short-time perception probably reflects subcortical vulnerability, and the change in PFC activity is possibly a by-product. Further studies are warranted to elucidate the processes involved.

As has been reported, short-time perception is modulated by affective states [51], an intense fever [52,53] and psychotic disorders [54,55]. Diurnal variation of short-time perception associated with the rest-activity cycle is expedient for adapting in daily life, similarly to the vegetative functions in blood circulation [56], aspiration [57], assimilation [58] or incretion [59,60]. These functions robustly synchronize to diurnal variation oscillated by a

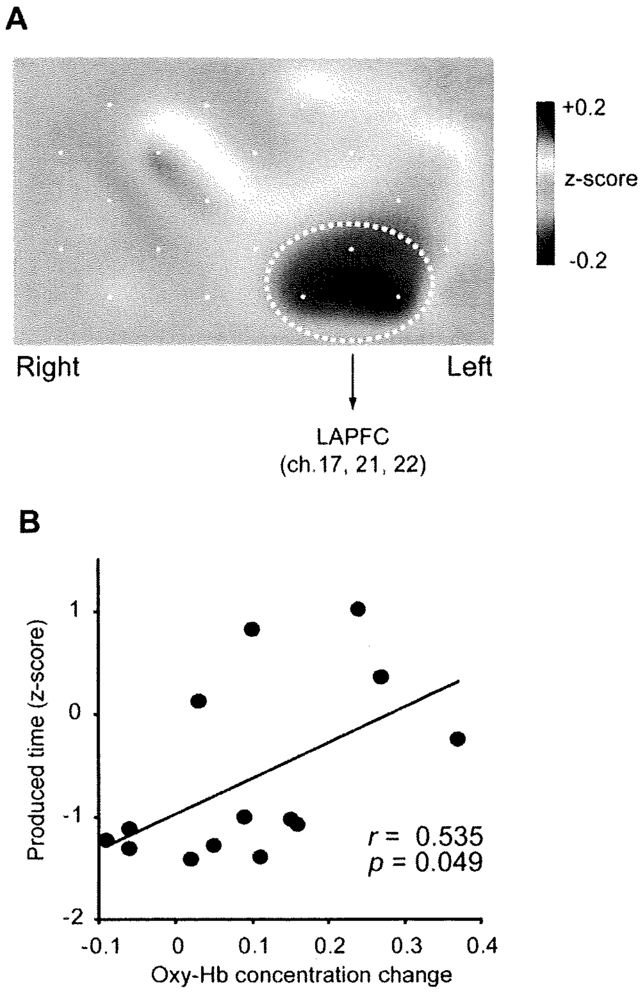

Figure 3. Change in hemodynamic response and functional correlation in prefrontal cortex (PFC) activity after sleep deprivation. (A) Topographic image representing increased activation in the PFC on day 2 in the SD condition (n = 14). The image is constructed by using subtracted values between the SC and the SD conditions (SD minus SC). The area of dotted white circles emphasizes the left anterior PFC (LAPFC) including chs. 17, 21 and 22 for region of interest (ROI) analysis. (B) Correlation between normalized produced intervals and oxy-Hb concentration changes in the LAPFC ROI on day 2 in the SD condition (n = 14). Functional connectivity in changes of short-time perception with LAPFC activity under sustained wakefulness is suggested by a correlation coefficient (*r*) of 0.535 with statistical significance ($p<0.05$).
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circadian pacemaker, and simultaneously prepare for desynchronization from diurnal variation under stressful conditions. Temporarily collapsing the diurnal variation of short-time perception may be an important function for surviving a crisis, such as in a situation with an acute emergency. Time perception in humans, as well as in other organisms, should be fundamentally synchronized to the physical state for constant adaptation to daily lifestyle regularity. However, once we are placed under stress, time perception must desynchronize from regular physical homeostasis and be shortened enabling time expansion and assumedly allowing us to adopt suitable strategies for coping with a stressful environment by doing or thinking of things more rapidly. Serious consideration of an adaptive nature of the human PFC function [61,62] suggests that the PFC might play a switch-like role in short-time perception as a situation demands, to meet the demands for adaptation.

Materials and Methods

Participants

Eighteen healthy right-handed males (mean age 22.4 yr; range 20–28 yr) participated in laboratory-based experiments in a 4-day protocol. A psychiatrist conducted a medical examination to confirm that none of the participants had a history of neurological or psychiatric disorder or abused psychoactive drugs. Participants were asked to avoid intake of caffeine, nicotine and alcohol for one week prior to and during the experiment. For one week before the experiment, they were also required to keep a regular sleep-wake habit in which they slept from around 00:00 and awoke at around 08:00, as confirmed by a sleep log and an activity recorder (Actiwatch-L, Mini-Mitter Co., Inc. Bend, OR). The mean habitual sleep duration was 6.5±0.1 h, and habitual sleep onset and wake times were 00:34±00:13 and 07:22±00:10, respectively. All procedures for the study were carried out in accordance with the principles outlined in the Declaration of Helsinki. The experimental protocol was approved by the ethics committee of the National Center of Neurology and Psychiatry, Japan. All participants gave written informed consent to take part in the study.

Experimental Protocol

All participants performed a 10-s TP task in the SC and SD conditions, scheduled in random order with a 1-day interval (Fig. 4). On the first day (day 1) in both the SC and SD conditions, participants arrived at the laboratory at about 18:00. fNIRS probe and optodes were attached to the surface of the scalp approximately one hour before the start of the TP session (at 20:00). The session, which lasted approximately 15 min, generally started around 21:00–22:00. After the end of the session, in the SC condition, the participants rested without sleep and exercise until 00:00 and then stayed in bed under complete darkness (<0.1 lux) until 08:00 on the second day (day 2). In contrast, in the SD condition, participants were asked to stay awake quietly under room light (100 lux) until 08:00 the next morning. During the nighttime period of enforced wakefulness, researchers monitored the participants' status via a video monitoring system. On day 2, the TP session started again around 09:00–10:00. All the experiments were performed at the time isolation facility of the National Center of Neurology and Psychiatry. The ambient temperature and humidity in the time isolation facility were maintained at 24.0±0.5°C and 60.0±5%, respectively, and temporal information was not provided to participants throughout the experimental schedule.

Time Production Task

TP tasks were arranged in an event-related design for detecting the hemodynamic response for a single trial. It has been confirmed that output of the task shows diurnal variation correlated with core body temperature or melatonin under a constant condition [7,13,26,28]. It shortens from morning into night, and is prolonged again from night to the next morning [7,13, 26,29].On the basis of our previous findings [26,27], TP sessions in the present study were conducted between 21:00–22:00 on day 1 and 09:00–10:00 on day 2, corresponding to the expected nadir and the peak periods of the diurnal variation of TP in the present participants with a regular sleep-wake cycle, respectively.

Each TP session consisted of 15 trials. The inter-trial interval was about 30 s. Participants were asked to produce a 10-s interval

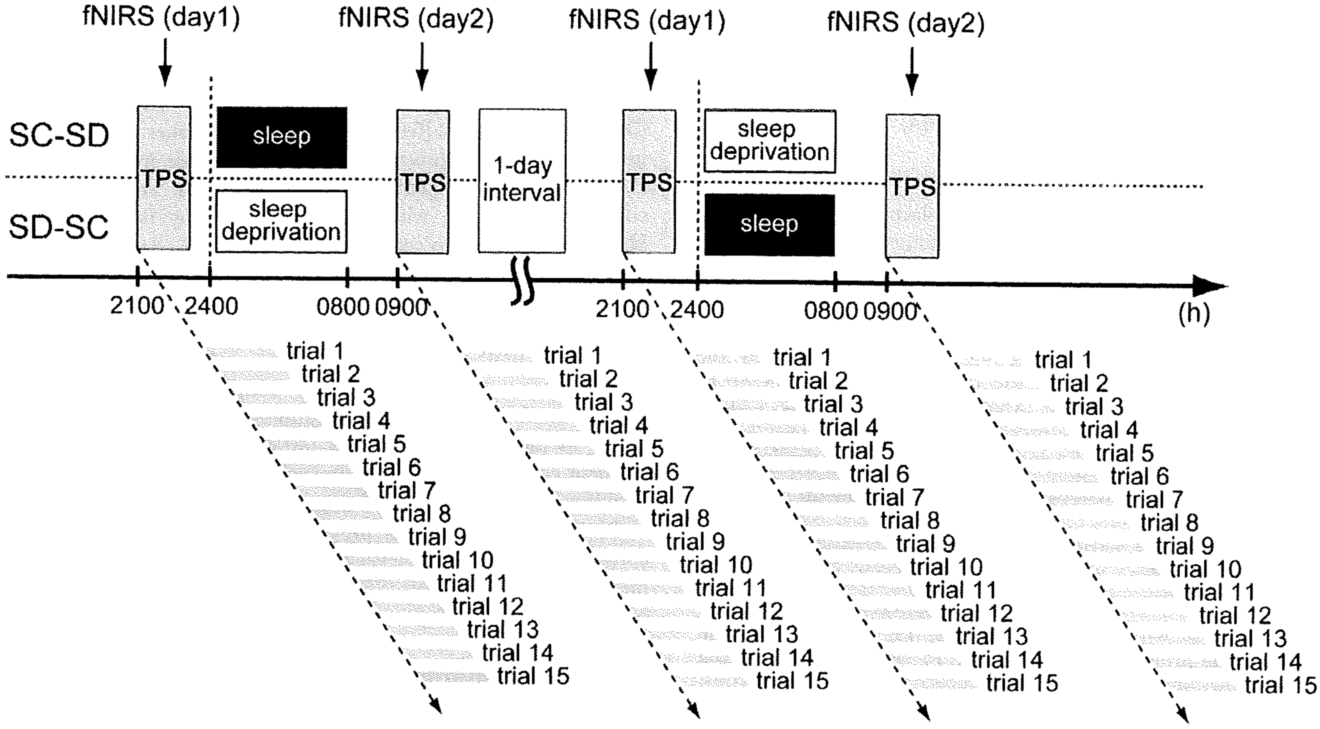

Figure 4. Experimental protocol. Time production sessions (TPS) were conducted twice at around 21:00 on day 1 and about 09:00 on day 2 in the sleep-controlled (SC) and the sleep-deprived (SD) settings. The two conditions were randomly scheduled with a 1-day interval. Each TPS included 15 trials, each of which participants started and ended with their own button presses. Functional near-infrared spectroscopy (fNIRS) data were recorded continuously through the sessions.
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and to begin and end each trial by pressing a key button [13]. Duration from the first to the second button presses was counted as the produced time. Participants were given no feedback about accuracy in the trials.

fNIRS Data Acquisition

Regional hemodynamic changes in brain tissue were monitored throughout the TP sessions by a continuous wave-type fNIRS system (OMM3000; Shimazu Co., Tokyo, Japan), which outputs near-infrared light at three wavelengths (780, 805 and 830 nm). All transmitted intensities of the three wavelengths were recorded every 130 ms at 22 channels in order to estimate concentration changes in oxy-Hb, deoxygenated hemoglobin and total hemoglobin, on the basis of the modified Beer-Lambert equation as a function of light absorbance of Hb and pathlength. A 3×5 optode probe was utilized, in which light detectors and emitters were alternately positioned at an equal distance of 3 cm. Based on the international 10–20 system [63], the lower central edge of each probe was suited above Fpz, along the reference curve of T3 - Fpz - T4. The 22 channels (see Fig. 5) probably covered the middle and superior PFC regions (BA9, 46, 10) [64].

fNIRS Data Analysis

Oxy-Hb data was chosen to examine event-related response in the PFC since it is an optimal index for changes of regional cerebral blood flow [65]. Data from 4 participants who were recruited to the experiment in the early stage were excluded from fNIRS analyses because they were monitored with a distinct optode probe. We applied a high-pass filter to raw data, re-sampled at 10 Hz, using the low-cutoff frequency of 0.05 Hz. Smoothing was performed by the moving average method (a boxcar filter) with a sliding time window of 1.1 s. Data were converted into z-scores by the normalization process [$(Xi-M)/SD$; where Xi is the value at each time point, M is the mean of all points and SD is the standard deviation of all points] [66]. Concentration changes time-locked to trial onset were extracted from 5 s before to 27 s after the onset, covering a mean produced time of about 11 s and a mean rest interval of about 16 s. A total of 15 epochs were obtained for each experimental day (day 1 or day 2) in each condition (SC or SD).

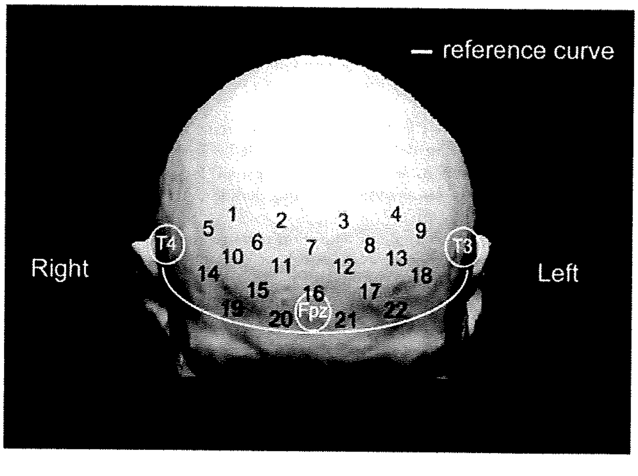

Figure 5. Approximate positions of 22 channels in fNIRS superimposed on the 3D head model. The 22 measuring channels were produced by optodes placed equidistantly over the prefrontal cortex (PFC) area. The lower line of the 3×5 optode probe was positioned along the reference curve linking T3, T4 and Fpz.
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Before individual averaging, baselines were corrected with mean z-scores of 5 s before trial onset. Grand averaged concentration changes in the LAPFC region, based on statistical analyses, were superimposed (Fig. 2), and subtracted values were utilized for reconstructing a topographic image (Fig. 3A).

Statistical Analysis

To examine whether the order of the sleep conditions [SC-SD (n = 7) vs. SD-SC (n = 11)] influenced outcomes of time production performance, we compared nocturnal sleep duration in both sleep schedules during the 1-day interval between the first and the second experiments and the sleep duration between the first and the second TP sessions during the participants' stay in the laboratory. We also analyzed the time production data of 18 participants using three-way ANOVA including two within-subject factors of condition (SC and SD) and day (day 1 and day 2), and a between-subject factor of schedule (SC-SD and SD-SC). If significant interactions were obtained, follow-up ANOVAs were conducted.

fNIRS data of 14 participants were tested separately for the lateral and the midline sites by overall ANOVA including within-subject factors of condition, day, hemisphere (left, right) and channel [9 chs: left, 1, 2, 5, 6, 10, 14, 15, 19, 20; right (the corresponding order): 4, 3, 9, 8, 13, 18, 17, 22, 21] for the lateral site, or factors of condition, day and channel (4 chs: 7, 11, 12, 16) for the midline area, utilizing mean z-scores of all temporal points (0–27 s). When the overall ANOVA reached statistical significance of the interaction coefficients, planed ANOVAs were subsequently performed with pooling error terms across the entire analyses, for the purpose to examine our assumption that sleep deprivation modulates the PFC activities on the time production trial. If degrees of freedom exceeded one degree, Greenhouse-Geisser correction was applied on the basis of the sphericity test. Depending on the topographic image reconstructed with subtracted values of changes in oxy-Hb concentration (SD minus SC; Fig. 3A), and a confirmed methodology for fNIRS probe placement [64], we defined the LAPFC, including chs. 17, 21 and 22, which corresponds to the medial dorsal part of the PFC (Brodmann's area 10) [64], as the ROI, and further examined the influence of sleep-deprivation on neural response in the LAPFC. Paired t-tests were performed for the ROI and the three constituent channels, with α levels adjusted by Benjamini and Hochberg's method to control the FDR [67]: $H_{(i)}$ denotes the null hypothesis based on the corresponding p-value $P_{(i)}$, $i = 1, 2, \ldots, m$. $P_{(i)}$ is increasingly ordered such as $P_{(1)} < P_{(2)} < \ldots < P_{(m)}$. The FDR control procedure starts with $i = m$, and continues to compare $P_{(i)}$ with $\alpha(i/m)$ until $P_{(i)}$ satisfy the constraint $P_{(i)} <$ or $= \alpha(i/m)$. The relation between produced times standardized within each participant and oxy-Hb concentration changes in the ROI on day 2 in the SD condition was tested with Pearson's product-moment correlation coefficient to examine functional connectivity between short TP and neural response of the LAPFC.

Outcomes of the tests for produced time and fNIRS data were considered significant at level α if $p<0.05$. Results are shown as mean and standard errors (SEs). Statistical analysis was performed by SPSS 12.0 J (SPSS Japan Inc., Tokyo).

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Author Contributions

Conceived and designed the experiments: TS KK SA ME KM. Performed the experiments: TS KK SA ME AH MT KM. Analyzed the data: TS KK KM. Wrote the paper: TS KK KM. Contributed to discussion: TS, KK, YK, KM. Supervised the entire project: KM.

References

1. Morell V (1996) Setting a biological stopwatch. Science 271: 905–906.
2. Ruan GX, Allen GC, Yamazaki S, McMahon DG (2008) An autonomous circadian clock in the inner mouse retina regulated by dopamine and GABA. PLoS Biol 6: 2249–2265.
3. Inoue ST, Kawamura H (1979) Persistence of circadian rhythmicity in a mammalian hypothalamic 'island' containing the suprachiasmatic nucleus. Proc Natl Acad Sci U S A 76: 5962–5966.
4. Moore RY, Silver R (1998) Suprachiasmatic nucleus organization. Chronobiol Int 15: 475–487.
5. Moore-Ede MC, Czeisler CA, Richardson GS (1983) Circadian time-keeping in health and disease. Part 1. Basic properties of circadian pacemakers. N Eng J Med 309: 469–476.
6. Gibbon J, Church RM (1981) Time left: linear versus logarithmic subjective time. J Exp Psychol Anim Behav Process 7: 87–107.
7. Aschoff J (1998) Human perception of short and long time intervals: its correlation with body temperature and the duration of wake time. J Biol Rhythms 13: 437–442.
8. Lewis PA, Miall RC (2003) Brain activation patterns during measurement of sub- and supra-second intervals. Neuropsychologia 41: 1583–1592.
9. Pouthas V, Geroge N, Poline JB, Pfeuty M, VandeMoorteele PF, et al. (2005) Neural network involved in time perception: an fMRI study comparing long and short interval estimation. Hum Brain Mapp 25: 433–441.
10. Rammsayer TH (2006) Effects of pharmacologically induced changes in NMDA receptor activity on human timing and sensorimotor performance. Brain Res 1073–1074: 407–416.
11. Mattel MS, Meck WH (2004) Cortico-striatal circuits and interval timing: coincidence detection of oscillatory processes. Cogn Brain Res 58: 119–124.
12. Rammsayer T, Ulrich R (2005) No evidence for qualitative differences in the processing of short and long temporal intervals. Acta Psychol 120: 141–171.
13. Kuriyama K, Uchiyama M, Suzuki H, Tagaya H, Ozaki A, et al. (2005) Diurnal fluctuation of time perception under 30-h sustained wakefulness. Neurosci Res 53: 123–128.
14. Maquet P, Lejeune H, Pouthas V, Bonnet M, Casini L, et al. (1996) Brain activation induced by estimation of duration: a PET study. Neuroimage 3: 119–126.
15. Rao S, Mayer AR, Harrington DL (2001) The evolution of brain activation during temporal processing. Nat Neurosci 4: 317–323.
16. Treisman M (1963) Temporal discrimination and the indifference interval implications for a model of the 'internal clock.' Psychol Monogr 77 (13): 1–31.
17. Ivry RB, Spencer RM (2004) The neural representation of time. Curr Opin Neurobiol 14: 225–32.
18. Zakay D, Block RA (2004) Prospective and retrospective duration judgments: an executive-control perspective. Acta Neurobiol Exp (Wars) 64: 319–28.
19. Casini L, Ivry RB (1999) Effects of divided attention on temporal processing in patients with lesions of the cerebellum or frontal lobe. Neuropsychology 13: 10–21.
20. Lewis PA, Miall RC (2002) Brain activity during non-automatic motor production of discrete multi-second intervals. Neuroreport 13: 1731–1735.
21. Harrington DL, Haaland KY, Knight RT (1998) Cortical networks underlying mechanisms of time perception. J Neurosci 18: 1085–1095.
22. Macar F, Lejeune H, Bonnet M, Ferrara A, Pouthas V, et al. (2002) Activation of the supplementary motor area and of attentional networks during temporal processing. Exp Brain Res 142: 475–485.
23. Livesey AC, Wall MB, Smith AT (2007) Time perception: manipulation of task difficulty dissociates clock functions from other cognitive demands. Neuropsychologia 45: 321–331.
24. Smith A, Lidzba K, Taylor E, Rubia K (2003) A right hemispheric frontocerebellar network for time discrimination of several hundreds of milliseconds. Neuroimage 20: 344–350.
25. Rubia K, Smith A (2004) The neural correlates of cognitive time management: a review. Acta Neurobiol Exp 64: 329–340.
26. Ashoff J, Daan S (1997) Human time perception in temporal isolation: effects of illumination intensity. Choronobiol Int 14: 585–596.
27. Miró E, Cano MC, Espinosa-Fernández L, Buela-Casal G (2003) Time estimation during prolonged sleep deprivation and its relation to activation measures. Hum Factors 45: 148–159.
28. Kuriyama K, Uchiyama M, Suzuki H, Tagaya H, Ozaki A, et al. (2003) Circadian fluctuation of time perception in healthy human subjects. Neurosci Res 46: 23–31.
29. Pöppel E, Giedke H (1970) Diurnal variation of time perception. Psychol Forsch 34: 182–198.

30. Aschoff J (1988) Circadian timing. Ann N Y Acad Sci 423: 442–468.
31. Horne JA (1993) Human sleep, sleep loss and behavior: implication for the prefrontal cortex and psychiatric disorder. B J Psychiatry 162: 413–419.
32. Drummond SPA, Brown GG (2001) The effects of total sleep deprivation on cerebral responses to cognitive performance. Neuropsychopharmacology 25 (5 suppl): S68–73.
33. Durmer JS, Dinges DF (2005) Neurocognitive consequence of sleep deprivation. Semin Neurol 25: 117–129.
34. Drummond SPA, Brown GG, Stricker JL, Buxton RB, Wong EC, et al. (2000b) Sleep deprivation-induced reduction in cortical functional response to serial subtraction. Neuroreport 10: 3745–3748.
35. Mu Q, Nahas Z, Johnson KA, Yamanaka K, Mishory A, et al. (2005) Decreased cortical activation response to verbal working memory following sleep deprivation. Sleep 28: 55–67.
36. Drummond SPA, Brown GG, Gillin JC, Stricker JL, Wong EC, et al. (2000a) Altered brain response to verbal learning following sleep deprivation. Nature 403: 655–657.
37. Drummond SPA, Gillin JC, Brown GG (2001) Increased cerebral response during a divided attention task following sleep deprivation. J Sleep Res 10: 85–92.
38. Chee MW, Choo WC (2004) Functional imaging of working memory after 24 hr of total sleep deprivation. J Neurosci 24: 4560–4567.
39. Hoshi Y, Tamura M (1993) Dynamic multichannel near-infrared optical imaging of human brain activity. J Appl Physiol 75: 1842–1846.
40. Villringer A, Planck J, Hock C, Schleinkofer L, Dirnagl U (1993) Near infrared spectroscopy (NIRS): a new tool to study hemodynamic changes during activation of brain function in human adults. Neurosci Let 154: 101–104.
41. Tononi G, Cirelli C (2006) Sleep function and synaptic homeostasis. Sleep Med Rev 10: 49–62.
42. Walker MP, Stickgold R (2004) Sleep-dependent learning and memory consolidation. Neuron 44: 121–133.
43. Kuriyama K, Stickgold R, Walker SP (2004) Sleep-dependent learning and motor skill complexity. Lean Mem 11: 705–713.
44. Kuriyama K, Mishima K, Suzuki H, Aritake S, Uchiyama M (2008) Sleep accelerates the improvement in working memory performance. J Neurosci 28: 10145–10150.
45. Aschoff J (1985) On the perception of time during prolonged temporal isolation. Human Neurobiol 4: 41–52.
46. Coull JT, Nobre AC (2008) Dissociating explicit timing from temporal expectation with fMRI. Curr Opin Neurobiol 18: 137–144.
47. Drummond SPA, Meloy MJ, Yanagi MA, Orff HJ, Brown GG (2005) Compensatory recruitment after sleep deprivation and the relationship with performance. Psychiatry Res 140: 211–223.
48. Rammsayer TH, Vogel WH (1992) Pharmacologic properties of the internal clock underlying time perception in humans. Neuropsychobiology 26 (1–2): 71–80.
49. Meck WH, Penny TB, Pouthas V (2008) Cortico-striatal representation of time in animals and humans. Curr Opin Neurobiol 18: 145–152.
50. Volkow ND, Wang GJ, Telang F, Fowler JS, Logan J, et al. (2008) Sleep deprivation decreases binding of $[^{11}C]$Raclopride to dopamine D_2/D_3 receptors in the human brain. J Neurosci 28: 8454–8461.
51. Angrilli A, Cherubini P, Pavese A, Mangfredini S (1997) The influence of affective factors on time perception. Percept Psychophys 59: 972–982.
52. Hoagland H (1933) The physiological control of judgments of duration: evidence for a chemical clock. J Gen Psychol 9: 267–287.
53. Kleber RJ, Lhamon WT, Goldstone S (1963) Hyperthermia, hyperthyroidism, and time judgment. J Comp Physiol Psychol 56: 362–365.
54. Tysk L (1984) Time perception and affective disorders. Percept Mot Skills 58: 455–464.
55. Bschor T, Ising M, Bauer M, Lewitzka U, Skerstupeit M, et al. (2004) Time experience and time judgment in major depression, mania and healthy subjects: a controlled study of 93 subjects. Acta Psychatr Scand 109: 222–229.
56. Kraft M, Martin RJ (1995) Chronobiology and chronotherapy in medicine. Dis Mon 41: 501–75.
57. Jindal SK, Aggarwal AN, Gupta D (2002) Diurnal variability of peak expiratory flow. J Asthma 39: 363–73.
58. Davidson AJ, Castañón-Cervantes O, Stephan FK (2004) Daily oscillations in liver function: diurnal vs circadian rhythmicity. Liver Int 24: 179–86.
59. Boyar RM, Witkin M, Carruth A, Ramsey J (1979) Circadian cortisol secretory rhythms in Cushing's disease. J Clin Endocrinol Metab 48: 760–5.
60. Fevre M, Segel T, Marks JF, Boyar RM (1978) LH and melatonin secretion patterns in pubertal boys. J Clin Endocrinol Metab 47: 1383–6.
61. Duncan J (2001) An adaptive coding model of neural function in prefrontal cortex. Nat Rev Neurosci 2: 820–829.
62. Miller EK, Cohen JD (2001) An integrative theory of prefrontal cortex function. Annu Rev Neurosci 24: 167–202.
63. Jasper HH (1958) The ten-twenty electrode system of international federation. Electroencephalogr Clin Neurophysiol 86: 7–14.
64. Okamoto M, Dan H, Sakamoto K, Takeo K, Shimizu K, et al. (2004) Three-dimensional probabilistic anatomical cranio-cerebral correlation via the international 10–20 system oriented for transcranial functional brain mapping. Neuroimage 21: 99–111.
65. Hoshi Y, Kobayashi N, Tamura M (2001) Interpretation of near-infrared spectroscopy signals: a study with a newly developed perfused rat brain model. J Appl Physiol 90: 1657–1662.
66. Matsuda G, Hiraki K (2006) Sustained decrease in oxygenated hemoglobin during video games in the dorsal prefrontal cortex: a NIRS study of children. Neuroimage 29: 706–11.
67. Benjamini Y, Hochberg Y (1995) Controlling the false discovery rate: a practical and powerful approach to multiple testing. J R Statist Soc B 57: 289–300.

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SCIENTIFIC INVESTIGATIONS

Non-Pharmacological Self-Management of Sleep Among the Japanese General Population

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Study Objectives: The present study was conducted to clarify the prevalence of non-pharmacological self-management (nPSM) practices for obtaining good sleep and to identify favorable nPSM practices that could be applied for reducing excessive daytime sleepiness (EDS). We analyzed epidemiological data for an authentic representative sample of the Japanese population.

Methods: Data obtained from 24,686 adults via a self-administered questionnaire completed in the Active Survey of Health and Welfare 2000 were used for analyses. The prevalence of individual nPSM practices was calculated by gender. Subsequently, the associations between such practices and EDS were examined using logistic regression analyses.

Results: "Having a bath" was the most prevalent nPSM practice for both men (59.0%) and women (64.4%), followed by "maintaining a regular schedule" (men: 49.0%, women: 58.6%), "reading or listening to music" (men: 43.4%, women: 49.4%), "snacking on food and/or beverages" (men: 36.1%, women: 27.9%), and "exercising" (men: 26.2%, women: 29.4%). The prevalence of "maintaining a regular schedule" increased with age. Multiple logistic regression analyses revealed that having a bath and maintaining a regular schedule had negative associations with EDS, whereas snacking on food and/or beverages had a positive association.

Conclusions: Having a bath and maintaining a regular schedule were identified as favorable nPSM practices for reducing EDS, whereas snacking on food and/or beverages was considered to be an unfavorable nPSM practice.

Keywords: Self-management, sleep, Japan, epidemiology, excessive daytime sleepiness, prevalence

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Sleep disturbance is known to be associated with the onset of mental disorders such as depression. It is also well known that sleep disturbance is an eventual risk factor for various somatic disorders such as diabetes mellitus, obesity, and cardiovascular disease.[1-5] In addition, excessive daytime sleepiness (EDS) resulting from sleep disturbance may lead to industrial and traffic accidents.[6-8] Thus, in developed countries, employing pertinent measures to prevent sleep disturbance is widely recognized as an important issue in promoting industrial hygiene and public health.

People in general use various non-pharmacological self-management (nPSM) strategies to obtain good sleep. However, most previous studies have focused on so-called pharmacological management practices such as the use of alcohol or hypnotic medications, and many epidemiological findings regarding such practices have been reported. For example, a study in the US reported that the prevalence of using hypnotic medications to improve the quality and quantity of sleep ranged from 10% to 18%, while that of consuming alcohol ranged from 10% to 13%, with the use of hypnotic medications being more prevalent among women and the consumption of alcoholic beverages more prevalent among men.[9] A study in Japan obtained similar findings with respect to the use of hypnotics (women: 5.9%, men: 4.3%),[10] and to the larger proportion of men consuming alcoholic beverages to induce sleep one or more times a week compared to women (48.3% and 18.3%, respectively).[10] Although physiological data associated with nPSM practices such as exercising, having a bath, reading, or snacking on food and/or beverages have been reported, few findings of epidemiological studies are available. In a survey of self-management practices employed by Americans to obtain sleep, Ancoli-Israel et al. found that the prevalence of exercising was higher among non-insomniacs than among insomniacs.[9] Morin et al. conducted a similar study of Americans and reported that the prevalence of reading was the highest, followed by listening to music.[11] However, no epidemiological study of nPSM practices for obtaining good sleep has been conducted in any Asian

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country to date. Therefore, in this study, we examined nPSM practices employed by the Japanese by examining data from an authentic, substantially large, representative sample of the Japanese population. We also analyzed the associations between each nPSM practice and EDS in order to identify those nPSM practices reported to be most effective.

METHODS

Selection of Participants

The present study was part of a national survey (Active Survey of Health and Welfare) organized by the Statistics and Information Department of the Ministry of Health, Labour and Welfare of Japan. This national survey was planned in order to collect basic information on health and welfare, and included questions concerning symptoms of depression and sleep. The survey was conducted through health centers across Japan.

The survey was administered to subjects from 300 census precincts in Japan selected randomly from among some 824,000 precincts, which had been apportioned for equal population size. Each census precinct was numbered from north to south, and 300 precincts were selected by choosing precinct numbers at certain intervals. As a result, the sample represented the entire country. A health center with jurisdiction for each precinct was designated. Investigators sent by these health centers visited all households to distribute the questionnaires, and collected them a few days later. The survey targets were all individuals aged 12 years or older in the 300 sampled precincts. The survey was conducted simultaneously throughout Japan in June 2000. Oral informed consent was obtained from the participants, and their privacy was protected in accordance with Declaration of Helsinki guidelines.

Measures

A self-administered questionnaire was devised by 2 of the authors (M.U. and T.O.) together with an appropriate official of the Ministry of Health, Labour and Welfare. The questionnaire comprised 44 items, including items on (1) sociodemographic information such as age, gender, and community size; (2) general health status; (3) physical and psychological complaints; (4) information on mental stress; and (5) sleep habits and sleep problems, as well as (6) the Japanese version of the Center for Epidemiologic Studies Depression Scale (CES-D). The CES-D, which is a 20-item inventory designed specifically to assess symptoms of depression in the general population, was used to screen for current depressive states during the one week leading up to the survey. This questionnaire is adequately reliable and valid for use in a general population. The CES-D yields an item score (range, 0–3) and the sum of the 20-item scores (range 0–60). Higher scores indicate increasing severity of depressive symptoms. Although this scale is designed to screen, but not diagnose, major depression, a score $\geq$ 16 is highly suggestive of depressive symptoms. Shima et al. developed the Japanese version of the CES-D, examined its reliability and validity, and recommended that the cut-off point be set at 16, as is the case for the American version of the CES-D. [12]

The following questions regarding sleep experienced during the previous month (listed here followed by the variables they targeted) were embedded in the questionnaire:

Question: Did you indulge in any of the following practices in the past month in order to sleep efficiently?

(1) I consumed alcoholic beverages. [1 = No; 2 = 1-2 times a month; 3 = 1-2 times a week; 4 = 3 or more times a week]
(2) I used medications such as hypnotic drugs. [1 = No; 2 = 1-2 times a month; 3 = 1-2 times a week, 4 = 3 or more times a week]
(3) I snacked on food and/or beverages. [1 = No; 2 = Yes]
(4) I performed light exercise. [1. No, 2. Yes]
(5) I had a bath. [1. No, 2. Yes]
(6) I read or listened to music. [1. No, 2. Yes]
(7) I tried to maintain a regular schedule. [1. No, 2. Yes]

With regard to (1) and (2), participants who consumed alcohol and who used medications one or more times a week were categorized as participants who "consumed alcohol" and "used medication," respectively.

With regard to sleep duration, we posed the question, "What was your average sleep duration per night?" Those who answered "less than 6 hours" were categorized as participants with "short sleep duration."

For subjective sleep insufficiency, participants were asked to respond to the question, "Have you had sufficiently restful sleep?" by selecting one of the following 4 options: "Sufficient," "Fairly sufficient," "Rather insufficient," and "Completely insufficient." Those who selected the latter 2 options were categorized as participants with "subjective insufficient sleep".

For excessive daytime sleepiness, we posed the question, "Have you experienced any difficulty in staying awake at times when you should not fall asleep (e.g., while you are driving)?" Those who responded affirmatively were classed as participants with "excessive daytime sleepiness."

Statistical Analyses

Questionnaires were returned by 32,729 participants. The Ministry of Health, Labour and Welfare did not publish the number of residences contacted in the target communities, and therefore the return rate could not be calculated. However, the collection rates of similar investigations carried out 3, 4, and 6 years previously were 87.1%, 89.6%, and 87.3%, respectively. It can be assumed that since the present study was performed using similar methods, the collection rate is likely to have been similar to the previous investigations. The Minister of Health, Labour and Welfare granted permission for us to use the survey data. Before analysis, 707 participants who submitted blank answer forms were excluded from the study. Participants under 20 years of age (N = 3086) were also excluded since this study was aimed at adults. In addition, participants who had not responded to the questions on gender and/or age were excluded (N = 222), as were participants who omitted 6 or more answers on the CES-D (N = 4028). Thus, data for a total of 24,686 participants (11,752 men and 12,934 women) were analyzed statistically.

For statistical analysis, the prevalence of each nPSM practice (snacking on food and/or beverages, exercising, having a bath, reading or listening to music, and maintaining a regular schedule) used as a sleep aid was calculated by gender and by age class. The significance of the categorical data, such as the prevalence of each nPSM strategy used as a sleep aid, was analyzed using the χ^2 test. Finally, logistic regression analyses were conducted to examine the factors associated with EDS by using 4 models with different adjustment factors. Model 1 was nonadjustable. Model 2 was adjustable, using gender, age class, place of residence, and severity of depression as covariates. In Model 3, short sleep duration and subjective insufficient sleep were added to the covariates of Model 2. In Model 4, consumption of alcohol and use of medication were further added to the covariates of Model 3.

Odds ratios were calculated from the univariate and multivariate logistic regression analyses with 95% confidence intervals. All analyses were performed using SPSS 12.0 for Windows (SPSS Inc., Chicago, IL)

RESULTS

Characteristics of the Participants

The demographic characteristics of the total 24,686 participants are shown in Table 1. Although the percentages of the men and women aged 70 years or older are slightly lower than those revealed by the census, the percentages of other groups are similar.

Prevalence of Non-pharmacological Self-management Practices

The prevalence of each of the 5 nPSM practices classified by gender is shown in Table 2; the prevalence of "having a bath" was highest among both men (59.0%) and women (64.4%), followed by "maintaining a regular schedule" (men: 49.0%, women: 58.6%), "reading or listening to music" (men: 43.4%, women: 49.4%), "snacking on food and/or beverages" (men: 36.1%, women: 27.9%) and "exercising" (men: 26.2%, women: 29.4%). For all the nPSM practices, age-related differences were identified among both men and women ($p < 0.001$). In particular, the prevalence of maintaining a regular schedule increased with age, with respective prevalence in men and women in their 20s at 35.6% and 46.1% compared with that in men and women in their 70s at 68.1% and 69.8%. In terms of gender-based differences, the prevalence of snacking on food and/or beverages was significantly higher among men than women ($p < 0.001$). However, the prevalences of other nPSM practices were significantly higher among women than men ($p < 0.001$).

Table 1—Demographic Characteristics of Analyzed Subjects in a Sample of the Japanese Adult General Population (N = 24,686)[a]

	Percentage in Age Group					
Data Set	**20-29 y**	**30-39 y**	**40-49 y**	**50-59 y**	**60-69 y**	**70+ y**
Present study						
Male (N = 11,752)	18	18	19	21	15	9
Female (N = 12,934)	18	18	18	20	14	12
Census						
Male	19	18	17	20	15	12
Female	17	16	16	19	15	17

[a]Data for both the present study and the census were obtained in 2000.

Table 2—Non-Pharmacological Self-Management by Gender and Age Expressed as Percentage

Age, y	N	Snacking on food and/or beverage,%	Exercising,%	Having a bath,%	Reading or listening to music,%	Maintaining a regular schedule,%
Male						
20-29	2151	35.8	26.1	50.7	55.5	35.6
30-39	2157	36.5	21.0	50.1	41.9	38.3
40-49	2251	39.6	25.2	58.9	37.7	49.1
50-59	2468	40.4	29.4	69.5	40.3	59.3
60-69	1712	29.8	31.8	69.1	39.2	64.3
70+	1013	23.0	27.6	66.4	40.0	68.1
Total	11752	36.1	26.2	59.0	43.4	49.0
Sig.1		$\chi^2 = 69.07$*	$\chi^2 = 45.84$*	$\chi^2 = 229.35$*	$\chi^2 = 141.36$*	$\chi^2 = 431.76$*
Female						
20-29	2329	28.8	26.7	56.7	56.5	46.1
30-39	2362	29.3	25.4	55.9	47.0	53.5
40-49	2368	31.4	30.9	69.4	50.0	61.0
50-59	2592	29.2	34.8	74.9	50.0	66.4
60-69	1766	21.1	37.4	68.9	49.7	65.8
70+	1517	20.2	23.3	64.5	35.4	69.8
Total	12934	27.9	29.4	64.4	49.4	58.6
Sig.1		$\chi^2 = 58.69$*	$\chi^2 = 87.67$*	$\chi^2 = 220.92$*	$\chi^2 = 113.49$*	$\chi^2 = 260.20$*
Sig.2		$\chi^2 = 127.85$*	$\chi^2 = 21.77$*	$\chi^2 = 52.75$*	$\chi^2 = 60.65$*	$\chi^2 = 160.15$*

Sig.1: χ^2 test, 2 (Each non-pharmacological self-management-Yes or No; Snacking on food and/or beverage, Exercising, Having a bath, Reading or listening to music and Maintaining a regular schedule) × 6 (age effect; 20-29, 30-39, 40-49, 50-59, 60-69, 70+)
Sig.2: χ^2 test, 2 (Each non-pharmacological self-management-Yes or No; Snacking on food and/or beverage, Exercising, Having a bath, Reading or listening to music and Maintaining a regular schedule) × 2 (gender effect; male, female)
*$p < 0.001$

Table 3—Logistic Regression Results for Prediction of Excessive Daytime Sleepiness (EDS) Among the General Adult Population (N = 24,686)

	Prevalence of EDS (%)	Model 1 Crude OR	Model 1 95% CI	Model 1 P-value	Model 2 Adjusted OR	Model 2 95% CI	Model 2 P-value	Model 3 Adjusted OR	Model 3 95% CI	Model 3 P-value	Model 4 Adjusted OR	Model 4 95% CI	Model 4 P-value
Snacking on food and/or beverage													
No	2.7												
Yes	4.0	1.50	1.26-1.80	< 0.01	1.36	1.11-1.67	< 0.01	1.34	1.09-1.65	0.01	1.42	1.15-1.76	< 0.01
Exercising													
No	3.1												
Yes	3.1	1.00	0.82-1.21	0.96	1.08	0.86-1.37	0.50	1.11	0.88-1.41	0.37	1.15	0.90-1.45	0.26
Having a bath													
No	3.6												
Yes	2.8	0.77	0.65-0.92	< 0.01	0.76	0.61-0.94	0.01	0.75	0.61-0.93	0.01	0.76	0.61-0.95	0.01
Reading or listening to music													
No	2.9												
Yes	3.4	1.20	1.01-1.42	0.04	1.17	0.95-1.44	0.13	1.13	0.92-1.39	0.24	1.12	0.91-1.38	0.28
Maintaining a regular schedule													
No	4.0												
Yes	2.2	0.54	0.45-0.64	< 0.01	0.62	0.51-0.77	< 0.01	0.71	0.57-0.88	< 0.01	0.71	0.57-0.88	< 0.01

Other Adjustment factors
Model 1: non-adjustment.
Model 2: sex, age, size of community and depression status.
Model 3: sex, age, size of community, depressive status, short sleep duration and subjective insufficient sleep.
Model 4: sex, age, size of community, depressive status, short sleep duration, subjective insufficient sleep, alcohol use and hypnotic medication use.
OR: odds ratio
CI: confidence interval

Logistic Regression Analyses

The results of the logistic regression analyses are shown in Table 3. In Model 1, snacking on food and/or beverages and reading or listening to music showed significant positive associations with EDS. In contrast, having a bath and maintaining a regular schedule showed significant negative associations with EDS. In Models 2-4, reading or listening to music showed no association with EDS, and snacking on food and/or beverages showed a positive association, while having a bath and maintaining a regular schedule showed negative associations with EDS.

DISCUSSION

In the present study, we examined the prevalence of nPSM practices to obtain good sleep and the associations between each nPSM practice and EDS. This study was of epidemiological significance in that the participants were randomly selected from a nationwide population and the sample size was large. In effect, the age structure of the participants (shown in Table 1) was very close to that found in the national census, which had been conducted during the same period. This indicates that the study population represents the general population of Japan. To our knowledge, no similar epidemiological study has been reported to date.

Among the nPSM practices examined in this study, the prevalence of having a bath was highest among both men and women, followed by maintaining a regular schedule. In the U.S., Ancoli-Israel et al. found that the prevalence of exercising was highest (75%) among three nPSM practices in subjects without sleep disturbance, followed by reading (9%) and relaxing.[9] The survey of Morin et al. of the general population in Canada demonstrated that among reading, receiving acupuncture, getting a massage, relaxing, and listening to music, the prevalence of reading was highest (32.5%), followed by listening to music (25.2%).[11] In the present study, exercising and reading were included among the choices of nPSM practices, although the prevalence of exercising (approximately 30%) was the lowest among the 5 practices. Exercising and reading were actively adopted as self-management practices for sleeping by participants in studies conducted outside Japan, and thus the selection of self-management practices for sleep appear to differ across countries. The practice of having a bath, the prevalence of which was the highest in the present study, was not an identified practice in the previous studies outside Japan. This may be attributable to the unique habit of the Japanese taking a nightly hot bath.

In the present study, the prevalence of maintaining a regular schedule increased with age, the highest prevalence being evident among participants in their 70s. This result coincides with those of previous studies conducted in the US.[13,14] It is inferred that with age, people tend to become more health conscious and prefer a good sleep at night and lively daytime activities.

In this study, we attempted to classify the examined nPSM practices into favorable and unfavorable types by calculating the odds ratios with regard to EDS. Given our findings, we propose the theory that by employing an nPSM practice showing a statistically and significantly low odds ratio with regard to EDS, a night-sleep problem could be resolved, in turn leading to a decrease in EDS. Moreover, we considered that such a practice would be a favorable one. Conversely, we considered an nPSM practice showing a significantly high odds ratio with regard to EDS could lead to a higher possibility of EDS, and hence would be an unfavorable nPSM. However, there may be cases where a person with a sleep disorder might employ an nPSM practice to prevent EDS, but not benefit from it. In such a scenario, the sleep disorder would be a confounding factor affecting the association between the nPSM practice and EDS. Furthermore, there may be other confounding factors besides sleep. Therefore, in this study, several logistic regression models were set up for inputting various covariates, including sleep duration and subjective sleep insufficiency, to adjust for the possible confounding factors. Despite this attempt, causal relationships can not be thoroughly discussed because this study was cross-sectional; however, since this study was conducted with an authentic, representative sample of the Japanese population, the results obtained may be beneficial for the design of future public health measures for achieving good sleep.

In relation to the above-mentioned theory, the results indicate that having a bath and maintaining a regular schedule are favorable nPSM practices, and that snacking on food and/or beverages is an unfavorable nPSM practice. These results are supported by those of other previous physiological studies. It has been reported that having a bath not only leads to an increase in body temperature, but also stimulates the thermoregulatory center, which promotes the lowering of body temperature and induces slow wave sleep.[15,16] Having a bath is also reported to shorten significantly subjective and objective sleep latency and wake time after sleep onset, and increase the duration of slow wave sleep.[17-19] A previous study revealed that greater distal vasodilatation, as indicated by the distal-proximal skin temperature gradient, could predict shorter sleep latency in healthy subjects.[20] Moreover, Pache et al. have reported that patients with vasospastic syndrome suffer prolonged sleep onset latency due to impaired capacity for distal vasodilation.[21,22] Furthermore, it has been reported that subjective sleep sufficiency is better in individuals when they take a bath before going to bed than when they do not.[19] Based on the results of these physiological studies, it is inferred that "having a bath" is a favorable nPSM practice that could improve the quality of night sleep and reduce EDS.

Although it is difficult to define maintaining a regular schedule, this practice would include waking up at a regular time in the morning, performing specific activities at specific times, and not staying up late at night. For an individual who has adopted this practice, the sleep-wakefulness rhythm related to daytime activities and rest at night is maintained. In addition to this sleep-wakefulness rhythm, biodynamic rhythms such as autonomic rhythms (including periodic changes in body temperature and blood pressure) and endocrinological rhythms (including the melatonin and cortisol secretory cycles) are maintained in an orderly manner.[23] However, when a person's schedule is irregular, these biodynamic rhythms are disrupted, ultimately affecting sleep.[13,24-26] Monk et al. reported that the quality of sleep was lower in individuals with irregular schedules than in those with regular schedules.[13,24] Manber et al. also reported that subjects who maintained a regular daily rhythm for 4 weeks showed improvement in their night sleep and significant reduction of subjective daytime sleepiness, as compared with controls who had irregular rhythyms.[25] The results of these previous studies are in accord with those of the present study, in which the odds ratio of maintaining a regular schedule with regard to EDS was low. Hence, these previous results support our theory that maintaining a regular schedule is a favorable nPSM practice.

In this study, we noted a significantly high odds ratio for snacking on food and/or beverages with regard to EDS, suggesting that it was an unfavorable nPSM practice. A previous epidemiological study reported that irregular eating habits and subjective sleep insufficiency were closely associated,[27] and eating before going to bed was reported elsewhere to activate the digestive system and impede the body and brain from preparing to have a good rest; thus, this practice eventually hampered good sleep.[28] Therefore, the practice of snacking on food and/or beverages may actually lead to hampered sleep and consequently induce EDS.

The results of the present study provide suggestions on the appropriate self-management practices that should be employed for obtaining good sleep and preventing EDS. Performing such favorable self-management practices is vital for preventing various mental and somatic disorders since sleep disturbance is a risk factor for such disorders. Therefore, the identification of such favorable and unfavorable self-management practices in this study will contribute not only to the prevention of EDS, but also to the planning of public health policies and measures.

This study had a few limitations. First, because the study was cross-sectional, a causal relationship could not be established. A follow-up study will be required to verify the results. Second, excessive sleepiness was evaluated by only one questionnaire item. In our future studies we plan to use epidemiological tools such as the Epworth Sleepiness Scale. Third, all data used were subjective and obtained from a self-administered questionnaire. Because we preferred data accumulation from a larger number of participants nationwide, physiological measurements could not be obtained. However, several studies have reported that self-reported data on sleeping habits coincide with physiological data to a certain extent.[29,30] Fourth, due to the limitation of space on our self-administered questionnaire, we could not adopt the social demographic items of confounding factors such as marital status, education, occupation, and income, and these remain the subject for further study.

To conclude, having a bath and maintaining a regular schedule appear to be favorable nPSM practices for obtaining good sleep, while snacking on food and/or beverages is an unfavorable practice, findings which can contribute to the planning of public health measures with respect to sleep.

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DISCLOSURE STATEMENT

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REFERENCES

1. Bixler EO, Kales A, Soldatos CR, Kales JD, Healey S. Prevalence of sleep disorders in the Los Angeles metropolitan area. Am J Psychiatr 1979;136:1257-62.
2. Ford DE, Kamerow DB. Epidemiologic study of sleep disturbances and psychiatric disorders. An opportunity for prevention? JAMA 1989;262:1479-84.
3. Vollrath M, Wicki W, Angst J. The Zurich study. VIII. Insomnia: as-

sociation with depression, anxiety, somatic syndromes, and course of insomnia. Eur Arch Psychiatry Neurol Sci 1989;239:113-24.

4. Weissman MM, Greenwald S, Nino-Murcia G, Dement WC. The morbidity of insomnia uncomplicated by psychiatric disorders. Gen Hosp Psychiatry 1997;19:245-50.
5. Kim K, Uchiyama M, Liu X, et al. Somatic and psychological complaints and their correlates with insomnia in the Japanese general population. Psychosom Med 2001;63:441-6.
6. El-Ad B, Korczyn AD. Disorders of excessive daytime sleepiness--an update. J Neurol Sci 1998;153:192-202.
7. Roth T, Roehrs TA. Etiologies and sequelae of excessive daytime sleepiness. Clin Ther 1996;18:562-76; discussion 561.
8. Roehrs T, Carskadon MA, Dement WC, Roth T. Daytime sleepiness and alertness. In: Kryger MH, Roth T, Dement WC, eds. Principles and practice of sleep medicine, 4th ed. Philadelphia: WB Saunders Company, 2005: 39-50.
9. Ancoli-Israel S, Roth T. Characteristics of insomnia in the United States: results of the 1991 National Sleep Foundation Survey. I. Sleep 1999;22 Suppl 2: S347-53.
10. Kaneita Y, Uchiyama M, Takemura S, et al. Use of alcohol and hypnotic medication as aids to sleep among the Japanese general population. Sleep Med 2007;8:723-32.
11. Morin CM, LeBlanc M, Daley M, Gregoire JP, Merette C. Epidemiology of insomnia: prevalence, self-help treatments, consultations, and determinants of help-seeking behaviors. Sleep Med 2006;7:123-30.
12. Shima S, Shikano T, Kitamura T, Asai M. A new self-rating scale for depression. Clin Psychiatry 1985;27:717-23.
13. Monk TH, Petrie SR, Hayes AJ, Kupfer DJ. Regularity of daily life in relation to personality, age, gender, sleep quality and circadian rhythms. J Sleep Res 1994;3:196-205.
14. Monk TH, Reynolds CF 3rd, Kupfer DJ, Hoch CC, Carrier J, Houck PR. Differences over the life span in daily life-style regularity. Chronobiol Int 1997;14:295-306.
15. Benedek G, Obal F, Jr. Lelkes Z, Obal F. Thermal and chemical stimulations of the hypothalamic heat detectors: the effects of the EEG. Acta Physiol Acad Sci Hung 1982;60:27-35.
16. Berger RJ, Palca JW, Walker JM, Phillips NH. Correlations between body temperatures, metabolic rate and slow wave sleep in humans. Neurosci Lett 1988;86:230-4.
17. Bunnell DE, Agnew J, A. Horvath SM, Jopson L, Wills M. Passive body heating and sleep: influence of proximity to sleep. Sleep 1988;11:210-9.
18. Horne JA, Reid AJ. Night-time sleep EEG changes following body heating in a warm bath. Electroencephalogr Clin Neurophysiol 1985;60:154-7.
19. Sung EJ, Tochihara Y. Effects of bathing and hot footbath on sleep in winter. J Physiol Anthropol Appl Human Sci 2000;19:21-7.
20. Krauchi K, Cajochen C, Werth E, Wirz-Justice A. Warm feet promote the rapid onset of sleep. Nature 1999;401:36-7.
21. Pache M, Kräuchi K, Cajochen C, et al. Cold feet and prolonged sleep-onset latency in vasospastic syndrome. Lancet 2001;14;358:125-6.
22. Kräuchi K, Gasio PF, Vollenweider S, et al. Cold extremities and difficulties initiating sleep: evidence of co-morbidity from a random sample of a Swiss urban population. J Sleep Res 2008;17:420-6.
23. Moore-Ede MC, Sultzman FM, Fuller CA. The clocks that time us. Harvard Univ Press, 1982;381-4.
24. Monk TH, Reynolds CF 3rd, Buysse DJ, DeGrazia JM, Kupfer DJ. The relationship between lifestyle regularity and subjective sleep quality. Chronobiol Int 2003;20:97-107.
25. Manber R, Bootzin RR, Acebo C, Carskadon MA. The effects of regularizing sleep-wake schedules on daytime sleepiness. Sleep 1996;19:432-41.
26. Taillard J, Philip P, Bioulac B. Morningness/eveningness and the need for sleep. J Sleep Res 1999;8:291-5.
27. Ohida T, Kamal A, Uchiyama M, et al. The influence of lifestyle and health status factors on sleep loss among the Japanese general population. Sleep 2001;24:333-8.
28. Uchiyama M, ed. Study project on diagnostic and therapeutic guidelines for sleep disorders. Annual report of the National Project team supported by the research grant for nervous and mental disorders from the Ministry of Health, Labor and Welfare, Japan, 2001. [in Japanese]
29. Frankel BL, Coursey RD, Buchbinder R, Snyder F. Recorded and reported sleep in chronic primary insomnia. Arch Gen Psychiatry 1976;33:615-23.
30. Hoch CC, Reynolds CF 3rd, Kupfer DJ, Berman SR, Houck PR, Stack JA. Empirical note: self-report versus recorded sleep in healthy seniors. Psychophysiology 1987;24:293-9.

Sleep Findings in Young Adult Patients with Posttraumatic Stress Disorder

Mitsunari Habukawa, Naohisa Uchimura, Masaharu Maeda, Nozomu Kotorii, and Hisao Maeda

Background: Laboratory sleep studies in posttraumatic stress disorder (PTSD) have not provided consistent evidence of sleep disturbance, despite apparent sleep complaints. Most of these studies have investigated middle-aged chronic PTSD subjects with a high prevalence of comorbidities such as substance dependence and/or personality disorder.

Methods: Ten young adult PTSD patients (aged 23.4 ± 6.1 years) without comorbidities of substance dependence and/or personality disorder underwent 2-night polysomnographic recordings. These sleep measures were compared with those of normal control subjects and were correlated with PTSD symptoms.

Results: Posttraumatic stress disorder patients demonstrated significantly poorer sleep, reduced sleep efficiency caused by increased wake time after sleep onset, and increased awakening from rapid eye movement (REM) sleep (REM interruption). We found significant positive correlations between the severity of trauma-related nightmare complaints and the percentage of REM interruption, as well as wake time after sleep onset.

Conclusions: The results indicate that trauma-related nightmares are an important factor resulting in increased REM interruptions and wake time after sleep onset in PTSD.

Key Words: Increased wake time after sleep onset, posttraumatic stress disorder, REM interruption, sleep disturbance, trauma-related nightmares, young adult sample

Impaired sleep is a common complaint among patients with posttraumatic stress disorder (PTSD). However, laboratory sleep studies of PTSD have not provided consistent evidence of sleep disturbances. Most studies have tested middle-aged chronic PTSD subjects typically decades after the traumatic events, except for a handful of studies that were conducted during the immediate aftermath of trauma (Lavie 2001). There are likely a number of factors affecting sleep when PTSD persists for many years. Possible factors considered to explain the discrepancies of objective findings may include differences of 1) the amount of time since the trauma, 2) the age of subjects, 3) the source of the trauma, 4) the acuity of the trauma, 5) many comorbid psychiatric disorders, 6) comorbidities of substance dependence, and 7) the administration of psychotropic medications.

Therefore, we investigated young adult and drug-naïve or drug-free PTSD patients without comorbidities of substance dependence and/or personality disorders, although we could not exclude patients with concomitant major depressive disorder due to its high prevalence. We tested polysomnographic recordings within 1 to 3.5 years after the trauma in these patients and correlated sleep measures with PTSD symptoms.

Methods and Materials

Ten PTSD patients were recruited from the inpatient unit and outpatient clinic in the Department of Neuropsychiatry, Kurume University Hospital. The diagnoses of all patients were confirmed as PTSD according to the Structured Clinical Interview for DSM-IV (SCID) (American Psychiatric Association 1994) criteria and by exceeding the cutoff value of 50 for the Clinician-Administered PTSD Scale (CAPS) (Blake *et al.* 1995). Subjects with comorbidities of substance dependence and/or personality disorders and those who could not be kept off psychotropic medication for at least 2 weeks prior to this study were excluded. Table 1 shows the background of all PTSD patients. Six of 10 patients had never been treated with any psychotropic medications. Four patients (patients 3, 5, 6, and 8) had been receiving a selective serotonin reuptake inhibitor (SSRI) or benzodiazepines and were required to undergo a washout period of at least 2 weeks.

Control data were obtained from 10 age- and sex-matched healthy subjects. The control subjects were recruited from medical school students and through newspaper advertisements. Their average age was 24.4 ± 9.7 years, which did not significantly differ from that of the PTSD patients. All patients and control subjects were free of physical diseases and other sleep disorders. Written informed consent was obtained from both groups.

All subjects underwent 2 consecutive nights of standard polysomnographic study. They went to bed at their chosen time, and all woke up naturally without an alarm. The records were hand-scored in 20-second epochs according to the criteria of Rechtschaffen and Kales (1968) by a technician blind to the subject's identity.

The extracted sleep measures included indices of sleep initiation and maintenance, sleep architecture, and rapid eye movement (REM) latency, REM interruption (minutes), percentage of REM interruption (%), and REM density. Rapid eye movement periods were determined according to the recently reported procedure (Mellman *et al.* 2002). For each REM period, we determined REM interruptions by summing the intrusive wake times during the REM period and adding the subsequent wake time to the last epoch of REM period before emerging to more than 2 minutes of non-REM sleep. However, if final awakening was derived from the final REM period, the subsequent wake time was not included as REM interruptions. Rapid

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Table 1. Background of PTSD Subjects

Case	Age (years)	Sex	Nature of Trauma	Time Since Trauma (months)	Concurrent Diagnoses	Trauma-Related Nightmare	Total Score in CAPS
1	18	M	Sea accident	8	MDD, PD	+	96
2	18	M	Sea accident	8	MDD	–	78
3	19	M	Sea accident	21	MDD	+	77
4	25	F	Vehicle crash	3	MDD	+	84
5	36	F	Vehicle crash	40	—	+	83
6	19	F	Vehicle crash	19	MDD	+	107
7	23	M	Vehicle crash	3	—	–	60
8	31	F	Vehicle crash	39	MDD	+	108
9	25	F	Rape survivor	10	MDD, PD	+	66
10	23	M	Fire accident	4	MDD	+	83
Mean	23.4			15.4			84.4
SD	6.1			14.1			17.1

CAPS, Clinician-Administered PTSD Scale; F, female; M, male; MDD, major depressive disorder; PD, panic disorder; PTSD, posttraumatic stress disorder.

eye movement interruption was calculated as the sum of REM interruptions for each REM period and the percentage of REM interruption was defined as (REM interruption [min]/total REM time [min] + REM interruptions [min]) × 100. Rapid eye movement density was determined by calculating the percentage of 2-second intervals containing at least one horizontal eye movement.

Sleep measures from the second night in both groups were compared by Mann-Whitney *U* test, with .05 as the level of significance. Furthermore, sleep measures were correlated with the total score and subscale scores in CAPS by Spearman rank correlation, with .05 as the level of significance. Multiplicity controlling experimental-wise *p*-value was not applied, since the correlation analysis was performed in an exploratory manner.

Results

The average bedtime of the PTSD subjects (11:01 PM) did not significantly differ from that of the control subjects (10:56 PM). Table 2 shows the comparison of sleep data between both groups. Rapid eye movement interruption and the percentage of REM interruption in the PTSD group was significantly increased compared with the control group. The PTSD group demonstrated significantly reduced sleep efficiency caused by increased wake time after sleep onset. The percentage of slow-wave sleep (SWS) in the PTSD group was significantly decreased compared with the control group. An apnea-hypopnea index in the PTSD group did not significantly differ from the control group (.93 and 1.23 events per hour).

Table 3 shows the correlations between the total score and subscale scores in CAPS and polysomnographic data. There were significant positive correlations between the nightmare score (Criterion B-2) and the percentage of REM interruption, as well as wake time after sleep onset ($R = .82$, $p = .0142$ and $R = .71$, $p = .0358$, respectively). There were significant negative correlations between the nightmare score (Criterion B-2) and sleep latency. In addition, there was a significant negative correlation between the avoidance of stimuli (Criterion C) and total sleep time.

Discussion

The presence of repeated nightmares in PTSD has been hypothesized as a dysfunction of REM sleep mechanisms (Ross *et al.* 1989) and several studies have reported elevated REM sleep phasic events such as greater REM density and motor activity

Table 2. Comparison of Sleep Data Between PTSD and Control Groups

	PTSD Group ($n = 10$)		Control Group ($n = 10$)		Analysis
Measurement	Mean	SD	Mean	SD	*p* Value
Total Sleep Time (min)	450.3	76.0	466.7	72.4	n.s.
Sleep Efficiency (%)	85.5	2.5	94.9	2.1	.0002
Sleep Latency (min)	25.6	21.0	12.9	7.5	n.s.
Waking Time After Sleep Onset (min)	35.9	19.7	11.1	6.6	.0041
Number of Arousals	22.7	10.1	12.1	7.3	.0280
Stage 1 Sleep (%)	11.6	5.7	6.8	2.8	n.s.
Stage 2 Sleep (%)	52.5	10.2	50.6	8.2	n.s.
Stage 3 and 4 Sleep (%)	7.9	7.4	18.1	7.9	.0041
REM Sleep (%)	20.7	4.6	22.7	4.9	n.s.
REM Latency (min)	88.8	37.3	92.5	46.0	n.s.
REM Density (%)	30.8	9.0	25.6	7.0	n.s.
REM Interruption (min)	12.8	12.1	2.3	1.8	.0354
Percentage of REM Interruptions (%)	10.6	8.1	2.2	1.8	.0247

Analysis, Mann-Whitney *U* Test.
n.s., nonsignificant; PTSD, posttraumatic stress disorder; REM, rapid eye movement.

Table 3. Correlations Between the Total Score and Subscale Scores in CAPS and Polysomnographic Data

	TST (min)	SE (%)	SL (min)	WASO (min)	Number Arousals	%SWS (%)	REM Density (%)	Percentage of REM Interruptions (%)
Total Score in CAPS	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Re-experiencing (Criterion B)	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Nightmare (Criterion B-2)	n.s.	n.s.	−.78 (p = .014)	.71 (p = .036)	n.s.	n.s.	n.s.	.82 (p = .014)
Avoidance of Stimuli (Criterion C)	−.65 (p = .049)	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Hyperarousal (Criterion D)	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Difficulty Initiating and Maintaining Sleep (Criterion D-1)	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

The correlation coefficient and p value by Spearman's rank correlation are shown.

CAPS, Clinician-Administered PTSD Scale; n.s., nonsignificant; REM, rapid eye movement; SE, sleep efficiency; SL, sleep latency; SWS, slow wave sleep; TST, total sleep time; WASO, wake-time-after-sleep-onset.

during REM sleep in chronic combat-related PTSD patients (Mellman *et al.* 1997; Ross *et al.* 1994a, 1994b).

One of the most notable findings in this study is the observation of REM interruption in PTSD patients, replicating the results of two recent studies (Breslau *et al.* 2004; Mellman *et al.* 2002). Mellman *et al.* (2002) tested prospective polysomnographic recordings in 21 injured subjects within a month of injury and found a more fragmented pattern of REM sleep in subjects developing PTSD by calculating the average duration of continuous REM sleep. Breslau *et al.* (2004) compared polysomnographic measures between 71 lifetime PTSD subjects and 212 control subjects in a community sample and reported increased brief arousal from REM sleep in PTSD subjects by calculating the rate per hour of shifts to stage 1 sleep and waking from REM sleep.

Another noteworthy observation is the significant positive correlation between the severity of trauma-related nightmares and the percentage of REM interruptions, as well as wake time after sleep onset. Adapting the REM sleep measures in the aforementioned studies (Breslau *et al.* 2004; Mellman *et al.* 2002) to our small sample, we could not find significant correlations between the nightmare score and those measures. Therefore, it may be important that the measurements of fragmented REM sleep should include not only intrusive wake times during the REM period but also the subsequent wake time to REM period to understand the relationships between nightmares and REM mechanisms in PTSD.

We do not have sufficient explanation for the negative correlations between trauma-related nightmares and sleep latency, but they may be in part related to prior observations that nightmares are rarely observed in the sleep laboratory (Fisher *et al.* 1970; Hartmann 1984) and the "guarded environment" may facilitate sleep initiation for patients with frequent nightmares. Regarding the negative correlations between the avoidance of stimuli and total sleep time, we speculate that avoidance symptoms may result in decreased going out into the sun and consequently produce reduced total sleep time.

Generally, our PTSD patients demonstrated unequivocal sleep maintenance impairments, along with decreased slow-wave sleep. These results diverge from most previous studies (Hurwitz *et al.* 1998; Klein *et al.* 2002; Ross *et al.* 1994a, 1994b). These different findings may be mainly due to the high sleep efficiency (94.9%) of the control group in this study; however, in fact, we found significant improvements of these sleep measures, along with the amelioration of PTSD symptoms after psychotropic medication (unpublished data). Our PTSD subjects were young adult and drug-naïve or drug-free PTSD patients without history of substance dependence; therefore, they may be vulnerable to PTSD-related sleep disturbances. They demonstrated no evidence of sleep apnea, although several previous studies tested middle-aged patients with chronic PTSD and reported a high incidence of sleep-related breathing disorders (Krakow *et al.* 2001). These different findings may result from differences of the age of subjects among studies.

Finally, confidence in these findings is tempered by several study limitations. The first limitation is the modest sample size in this study. The second limitation is the high comorbidity (80%) of major depressive disorder (MDD); therefore, we could not determine particularly whether the decreased percentage of SWS was derived from PTSD or concomitant MDD. Other limitations include the differences in the amount of time since the trauma and trauma characteristics. Despite these limitations, our findings suggest that trauma-related nightmares may be an important factor resulting in REM interruptions and wake time after sleep onset in PTSD. Attempts to test these findings under controlled conditions in larger samples may further advance the understanding of the relationship between sleep and PTSD.

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American Psychiatric Association (1994): *Diagnostic and Statistical Manual of Mental Disorders: DSM-IV, 4th ed.* Washington, DC: American Psychiatric Press.

Blake DD, Weathers FW, Nagy LM, Kaloupek DG, Gusman FD, Charney DS, *et al.* (1995): The development of a Clinician-Administered PTSD scale. *J Trauma Stress* 8:75–90.

Breslau N, Roth T, Burduvali E, Kapke A, Schultz L, Roehrs T (2004): Sleep in lifetime posttraumatic stress disorder: A community-based polysomnographic study. *Arch Gen Psychiatry* 61:508–516.

Fisher C, Byrne J, Edwards A, Kahn E (1970): A psychophysiological study of nightmares. *J Am Psychoanal Assoc* 18:747–782.

Hartmann E (1984): *The Psychology and Biology of Terrifying Dreams.* New York: Basic Books.

Hurwitz TD, Mahowald MW, Kuskowski M, Engdahl BE (1998): Polysomnographic sleep is not clinically impaired in Vietnam combat veterans with chronic posttraumatic stress disorder. *Biol Psychiatry* 44: 1066–1073.

Klein E, Koren D, Arnon I, Lavie P (2002): No evidence of sleep disturbance in posttraumatic stress disorder: A polysomnographic study in injured victims of traffic accidents. *Isr J Psychiatry Relat Sci* 39:3–10.

Krakow B, Melendrez D, Pedersen B, Johnston L, Hollifield M, Germain A, *et al.* (2001): Complex insomnia: Insomnia and sleep-disordered breathing in a consecutive series of crime victims with nightmares and PTSD. *Biol Psychiatry* 49:948–953.

Lavie P (2001): Current concepts: Sleep disturbances in the wake of traumatic events. *N Engl J Med* 345:1825–1832.

Mellman TA, Bustamante V, Fins AI, Pigeon WR, Nolan B (2002): REM sleep and the early development of posttraumatic stress disorder. *Am J Psychiatry* 159:1696–1701.

Mellman TA, Nolan B, Hebding J, Kulick-Bell R, Dominguez R (1997): A polysomnographic comparison of veterans with combat-related PTSD, depressed men, and non-ill controls. *Sleep* 20:46–51.

Rechtschaffen A, Kales A (1968): *A Manual of Standardized Terminology, Techniques and Scoring System for Sleep Stages of Human Subjects.* Washington, DC: U.S. Government Printing Office.

Ross RJ, Ball WA, Dinges DF, Kribbs NB, Morrison AR, Silver SM, *et al.* (1994a): Rapid eye movement sleep disturbance in posttraumatic stress disorder. *Biol Psychiatry* 35:195–202.

Ross RJ, Ball WA, Dinges DF, Kribbs NB, Morrison AR, Silver SM, *et al.* (1994b): Motor dysfunction during sleep in posttraumatic stress disorder. *Sleep* 17:723–732.

Ross RJ, Ball WA, Sullivan KA, Caroff SN (1989): Sleep disturbance as the hallmark of posttraumatic stress disorder. *Am J Psychiatry* 146: 697–707.

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Bedtime Activities, Sleep Environment, and Sleep/Wake Patterns of Japanese Elementary School Children

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Bedtime activities, sleep environment, and their impact on sleep/wake patterns were assessed in 509 elementary school children (6–12 years of age; 252 males and 257 females). Television viewing, playing video games, and surfing the Internet had negative impact on sleep/wake parameters. Moreover, presence of a television set or video game in the child's bedroom increased their activity before bedtime. Time to return home later than 8 p.m. from after-school activity also had a negative impact on sleep/wake patterns. Health care practitioners should be aware of the potential negative impact of television, video games, and the Internet before bedtime, and also the possibility that late after-school activity can disturb sleep/wake patterns.

Sleep/wake patterns are strongly influenced by sleep habits, and sleep habits are largely influenced by social backgrounds and cultural standards. Therefore,

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understanding the factors related to sleep habits is important for the prevention of sleep disturbance. The demands of today's "24-hour society" have increased nighttime activity and affected sleep/wake patterns of not only adults but also children. In addition, sleep/wake patterns may also be influenced by usage of video games, cell phones, and the Internet.

A nationwide lifestyle survey in Japan, which has been conducted every 5 years by the Broadcasting Culture Research Institute, showed that mean sleep duration has decreased about 40 minutes on weekdays and about 30 minutes on Sundays within the past 25 years (Broadcasting Culture Research Institute, 2005). This dramatic decrease of sleep duration may largely be attributed to the aforementioned change of lifestyle of the Japanese population.

Children's sleep is affected by changes of lifestyle or the social system. For example, abolition of Saturday classes all over Japan resulted in a more than 40-min increase in mean sleep duration of teenagers on Saturdays (Broadcasting Culture Research Institute, 2005).

Cultural differences could produce a huge difference in sleep habits and sleep/wake parameters (e.g., bedtime, wake time, and sleep duration). Previous reports indicated that sleep duration is shorter among adolescents in Japan than in the United States or European countries (Fukuda & Ishihara, 2001; Tynjala, Kannas, & Valimaa, 1993; Wolfson & Carskadon, 1998). The percentage of 3-year-old children who go to bed later than 10 p.m. was reported to be very high (52%) in Japan compared to that in Australia (4.1%; Japanese Society of Child Health, 2001; see also Armstrong, Quinn, & Dadds, 1994). These reports indicate that children's sleep/wake patterns can vary significantly between cultures.

Decreased nocturnal sleep among children may be due to (a) the sleep/wake pattern of their parents; or (b) the influence of distractions such as television, videos or DVDs, the Internet, video games, and cell phones, which may monopolize the child's attention for a long time. Playing video games and Internet surfing are becoming more prevalent among children. In the United States, 81% of American youths reported playing video games at least once a week, and video game playing could be considered pathological in 8.5% of youths (Martin & Oppenheim, 2007). In Japan, 92% of fifth-grade children have video or portable games (Japanese Parent Teacher Association, 2007). Use of the Internet is also becoming prevalent among adults and children. A recent survey revealed that the percentage of Internet users was higher among teenagers (16%–20%) than the community at large (13%–15%; Broadcasting Culture Research Institute, 2005). Moreover, most cell phones currently available in Japan are equipped with Web browsing and e-mail transmission capability. Use of this device at bedtime may increase the likelihood of disturbing sleep.

Van den Bulck (2004) reported that television viewing, computer game playing, and Internet use significantly affects sleep among adolescents. Although the use of video games, cell phones, and Internet among smaller children has increased, the usage of these items before bedtime has not yet been correlated with sleep/wake patterns of elementary school children.

The aims of the study were first to identify activities that elementary school children do frequently before bedtime, and second, to elucidate the relationship between these activities and sleep/wake patterns of Japanese children.

METHOD

Participants

The study was conducted at a public elementary school located in the suburbs of Osaka, the second-largest city in Japan, in a middle-class residential district. A questionnaire was given to all students ($N = 582$) of the school. Our study included 509 participants (252 males, 257 females), who responded to the questionnaire and answered the questions properly (response rate: 86.9%). The mothers in 484 (95.1%) cases, fathers in 18 (3.5%) cases, both the mother and father in 5 (1.0%) cases, and grandparents in 2 (0.4%) cases completed the questionnaire.

Measures

The questions asked about bedtime activities, the environment of the bedroom, bedroom sharing, after-school activities, and sleep/wake patterns. Parents were asked to assess their child's sleep and behavior during an average week.

Bedtime activities. Bedtime activities including television viewing, playing video games, talking over the telephone, and use of the Internet were examined. Watching videos or DVDs was included with television viewing; playing portable games was combined with playing video games. Use of the Internet included Web browsing and e-mail transmission either on a personal computer or via the Internet on a cell phone. Parents were asked to check if their child engaged in these activities more than twice a week. More than twice weekly (the median frequency of media use found in a previous national study) was chosen as the threshold of activity (Japanese Ministry of Internal Affairs and Communication, 2007).

Bedroom facilities. Parents were asked whether items such as television sets, personal computers, cell phones or telephones, and video games or portable games were present or taken into the bedroom.

Bedroom sharing. Parents were asked whether the child slept with other members of the family in the same bedroom (room sharing). If so, the member who shared the bedroom was specified.

After-school activity. Questions were asked about after-school activities including extra schooling, music lessons (such as piano and violin lessons), and sports lessons.

Sleep measures. Questions were asked about bedtime, wake time, and estimated duration of sleep for both average weekdays and weekends.

Procedure

The questionnaire was given to all the children of the school. Parents or guardians were asked to fill out the questionnaire, which was collected at school. The 1-week survey was conducted in October 2006 when the climate is mild and no major school activities (such as sports events, school festivals, or national holidays) were scheduled, so that we could avoid the influence of seasonal or event-related factors.

Statistical Analyses

Comparison of categorical variables (sex difference in bedtime activities and bedroom environment, and relationship between bedtime activities and bedroom environment) was made using a chi-square test. Two group comparisons were done using the Mann–Whitney U test for continuous variables.

A series of multivariate logistic regression analyses were performed to examine the factors associated with sleep/wake parameters. Six logistic models regarding sleep/wake parameters both on weekdays and weekends as response variables (bedtime after 10 p.m., wake time after 8 a.m., and sleep duration of less than 9 hr) were created. In addition, three logistic models regarding sleep/wake parameters between weekdays and weekends as response variables (later bedtime of more than 1 hr, later wake time of more than 2 hr, and longer sleep duration of more than 2 hr on holidays) were also created. As covariates, sex, school grade (lower grade or higher grade), bedtime activities, bedroom environment, and time to return home from after-school activity were used in common. All variables were initially examined in univariate models, then we performed multivariate logistic regression analysis for all variables that showed a significant correlation in univariate models. Odds ratios (ORs) and their 95% confidence intervals (CIs) are presented to show the association. All the statistical analyses were conducted using SPSS 11.5 for Windows. Significance levels were set at $p < .05$.

RESULTS

Demographics of the Participants

The number of participants in each school grade was 85 (45 males, 40 females) in the first grade, 96 (50 males, 46 females) in the second grade, 84 (37 males, 47 females) in the third grade, 93 (45 males, 48 females) in the fourth grade, 77 (43 males, 34 females) in the fifth grade, and 74 (32 males, 42 females) in the sixth grade. The children ranged in age from 6 years old (1st-grade student) to 12 years old (6th-grade student), and their mean age was 9.0 ± 1.8 years.

The percentage of children who slept with family members in the same bedroom (room sharing) was 85.3% including 21.8% who slept with siblings, 22.0% who slept with parents, and 40.5% who slept with both siblings and parents. The rate of room sharing decreased with advancing grade (Figure 1).

Activities Before Bedtime

The percentage of children who watched television before bedtime was 80.9%. As shown in Figure 2, television viewing was the most prevalent bedtime activity, and the rate of television viewing did not vary significantly with school grade. The percentage of children who played video games or portable games before bedtime was 30.6%. Use of the Internet was seen in 7.1% of children, and its rate of use increased with advancing age (Figure 2). Although there was no sex difference in television viewing ($p = .262$), playing video games was

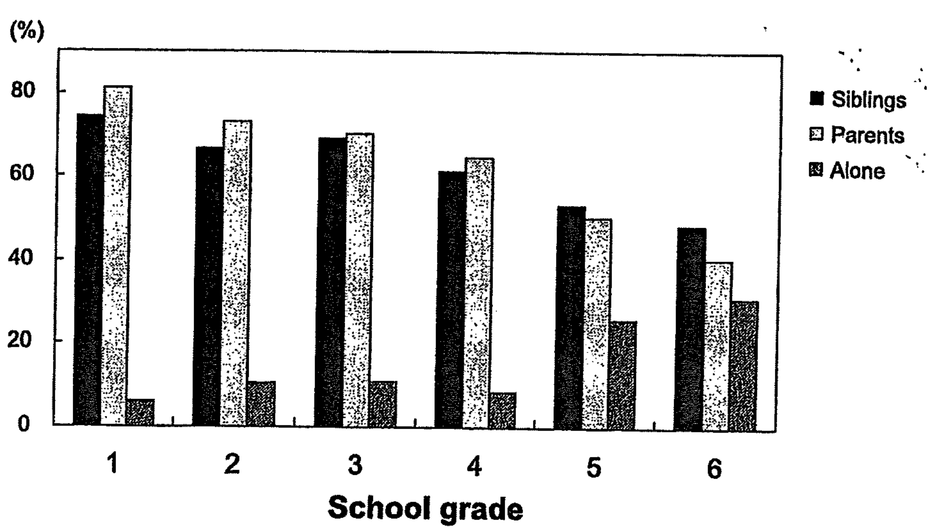

FIGURE 1 Percentage of children who slept with other family members in the same room (bedroom sharing).