Industrial Health 2005, **43**, 179–185 **Original Article**

Self-Awakening Prevents Acute Rise in Blood Pressure and Heart Rate at the Time of Awakening in Elderly People

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Received June 9, 2004 and accepted August 3, 2004

Abstract: Self-awakening, waking up at a designated time decided before sleeping, could prevent failure in the blood circulation vessel system such as heart attack, acute increases in heart rate or blood pressure upon waking. Previous research showed that anticipatory changes occurred in heart rate prior to awakening from a short nap by means of self-awakening for young participants. However, the effects of self-awakening remained unclear for elderly people. The present study examined the effects of self-awakening on heart rate and blood pressure in a short afternoon nap (20 min) among the elderly. Nine participants [74.1 (*SD* = 5.01) years old] underwent both self-awakening and forced-awakening conditions. In the self-awakening condition, it was revealed that blood pressure gradually increased before the scheduled time of awakening, and that heart rate did not show a rapid increase at arousal. In contrast, forced-awakening induced acute increases in both heart rate and blood pressure. These results suggest that self-awakening facilitates a more smooth transition from sleep to wakefulness via autonomic activation before the time of self-awakening.

Key words: Short daytime nap, Blood pressure, Heart rate, Self-awakening, Elderly people

Introduction

It is well known that severe sleepiness often occurs in the afternoon (i.e., post lunch dip[1–3]). In the countries which have the custom of siesta such as Latin America and Spain, people take a nap to avoid the hottest part of the day[4]. Even in the countries which do not have the custom of siesta, a short nap (i.e., "power nap") is recommended to reduce afternoon sleepiness[5, 6]. Many studies have indicated that psychomotor vigilance performance and subjective sleepiness improve after a short nap[5–8], suggesting napping as an effective measure to maintain productivity and safety at work. In the elderly, it has been reported that the risk of Alzheimer's disease may be reduced by habitual short naps[9].

Undesirable effects of napping, however, have been duly noted. Sleep inertia, which is severe sleepiness and poor performance immediately after the nap[10], is one of the problems. This can be moderated by limiting the length of a nap, since awakening from a long nap (> 30 min) with deep sleep would increase sleep inertia[5, 10]. Another problem is thought to be the increased risk of a coronary heart attack related to the daytime nap[11–14]. Acute increases in heart rate and blood pressure at awakening are associated with these problems[15]. When we awaken by means of external stimuli such as an alarm clock or someone's voice, our blood pressure and heart rate would increase, and these changes might trigger a heart attack.

Because of arteriosclerosis—as one ages, the large arteries

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lose their normal flexibility and become thickened and stiff[16], thus, degrading their elastic capabilities—, the systolic blood pressure increases in the older, stiffer arteries more than in a younger softer artery. Therefore, elderly people may be at risk of sudden increased blood pressure upon awakening[17, 18].

Self-awakening could be useful, as a means of preventing these sudden increases in heart rate and blood pressure. Some people are known to have the ability to wake themselves from a period of undisturbed sleep at a pre—designated time chosen before sleep[19–21]. This ability is called "self-awakening"[21]. Nearly 50% of people can wake precisely at a given hour determined before sleep[20]. Born *et al.* (1999) demonstrated that adrenocorticotrophin in serum increases gradually before the end of sleep due to the intention to self-awaken[22]. Adrenocorticotrophin affects the autonomic nervous system and, thereby, heart rate and blood pressure may gradually increase before the end of sleep by self-awakening. In a previous afternoon nap study, we tested this possibility among young participants and showed that the intention to self-awaken increased heart rate about three min before arousal[23]. However, it was still unclear as to the specific responses of the elderly.

In the present study, we examined the effect of self-awakening on heart rate and blood pressure in elderly people. The hypothesis was that the acute increases in heart rate and blood pressure after awakening would be suppressed by self-awakening among older participants also.

Participants and Methods

Participants

Participants were 10 elderly people. One participant was unable to induce self-awakening, therefore the data analysis was carried out on nine participants [74.1 (SD = 5.01, Range = 65–80) years old; 7 males and 2 females]. They were selected according to the following criteria: (1) a regular sleep-wake cycle was required at least one month before the experiment, (2) a short nap (< 30 min) was taken more than four times a week in the afternoon, (3) no complaints were reported about their sleep, (4) self-awakening could be achieved during regular nighttime sleep, (5) there were reasonable expectations for their ability to self-awaken from a nap, (6) the absence of severe physical and psychiatric disorders which may disturb sleep. One week before to the experiment, participants were requested to maintain a well-regulated lifestyle including adequate nighttime sleep. Consumption of alcoholic beverages and cigarettes was prohibited. Participants did not take medications except an antihypertensive drug that was used by six out of nine participants. On the day of experiment, participants were asked to abstain from caffeine. They were asked to record their sleep-wake patterns in a sleep diary and this was used to confirm their compliance with the instructions.

The purpose of the experiment was explained to the participants and they signed their informed consent. The protocol of the experiment was reviewed and approved by the Ethical Committee for Research Involving Humans at Hiroshima University, Japan.

Procedure

Participants took part in both self-awakening and forced-awakening conditions. In the self-awakening condition, participants took a nap for 20 min from the time that the lights were turned off and they woke by means of self-awakening (i.e., without any external means). The success range of self-awakening was to be within ± five min of the appointed time. In the forced-awakening condition, participants were instructed to self-awaken in 40 min after the lights off, but they were awoken by the voice of the experimenter after 20 min. The naps began at their usual napping time between 12.00 h and 16.00 h. In the experiment, each participant took a nap in the supine position on a bed as they used to do. The order of the two experimental conditions was counterbalanced between the participants. Before each experimental condition, an adaptation day was arranged to acclimatize them to the experimental environment. The adaptation day was planned with the same schedule as the self-awakening condition, so that they could practice self-awakening before both experimental days. The interval between the two conditions including the adaptation day was at least two days.

The experiment was carried out in the participants' home to reduce the "first day effect", which is equivalent to the "first night effect" for napping. This "first day effect" which occurs in an unaccustomed environment, seems to have a more apparent and severer effect on the elderly than on the young[24].

The experiment was conducted from September to November 2001, and from April to July 2002. Mild weather with respect to temperature and humidity at these times aided nap taking.

Measurements

Electrodes were attached at C3 and O1 on scalp sites[25] for an electroencephalogram (EEG), outside of both the canthi for an electro oculogram (EOG), and at the chin for an electromyogram (EMG). The sampling rate for recording was 500 Hz and the time constants were 0.3 sec for the EEG,

Table 1. The environment at the experiment

	Self-awakening	Forced-awakening	t	$p <$
Temperature (°C)	21.8 (1.54)	20.3 (1.49)	1.60	n.s.
Humidity (%)	59.6 (3.99)	58.3 (3.59)	0.07	n.s.
Illumination (lux)	44.3 (15.59)	36.3 (12.06)	0.52	n.s.
Noise (dB/SPL)	28.9 (1.34)	28.7 (1.02)	0.09	n.s.

Values in parentheses show SE.

3.2 sec for the EOG and 0.03 sec for the EMG. The electrophysiological data were recorded with a portable digital recorder (Polymate AP1000, Digitex laboratory Co., LTD, Japan).

Blood pressure and heart rate were measured with a finger blood pressure measuring device (Portapres model 2 TNO Biomedical Instrumentation, Netherlands) per one beat of heart on the left middle finger. This device is unsuitable for measuring the absolute blood pressure value, but it is useful for measuring the variation from a baseline. This device also has a feature by which diastolic blood pressure can be measured more reliably than systolic blood pressure[26, 27]. In spite of the disadvantages of this device, it is advantageous for measuring blood pressure during sleep continuously without serious sleep disturbance. In order to obtain the absolute value of the anteromedial blood pressure, another device (USM-700GV, Elquest Corporation, Japan) was used. Arterial blood pressure was measured twice, immediately before napping after a two min rest in the supine posture, and immediately after napping. Each measurement was taken for three minutes.

Data analysis

Sleep stages were visually scored every 20 sec according to the criteria of Rechtshaffen & Kales (1968)[28]. To complement the Rechtshafen & Kales criteria, those of the Sleep Computing Committee of the Japanese Society of Sleep Research (JSSR) (2001)[29] were also applied. Micro arousals during the naps were judged by the criteria of the American Sleep Disorders Association and the Sleep Research Society (1992)[30]. Micro arousal was defined as three seconds of alpha activity during stable sleep[30].

Finger blood pressure and heart rate were averaged every 20 s. Heart rate and blood pressure data were transformed to deviations from the baseline because of the wide interparticipant variation. The baseline was measured as the average value for the one minute rest period before the nap. Data from the adaptation day were not used for the analysis.

Statistical analysis

The data were submitted to a Condition (self-awakening and forced-awakening) × Time (elapsed time) repeated measure analysis of variance (ANOVA) with the SPSS system for Windows, version 11.5. To control the type I error associated with the violation of the sphericity assumption, degrees of freedom greater than one were reduced by the Huynh-Feldt ε correction. Post hoc analysis was made with Tukey's procedure and the paired t test.

Results

Characteristics of the participants and environment of the experiment

Participants were habitual short nap takers [4.6 (SD = 0.75) times per week and average napping duration was 32.1 (SD = 4.64) min]. Bedtime one day before the experiment was 22.08 h (SD=19.71 min) and sleep duration was 400.0 (SD = 17.74) min. Naps began at 13.21 h (SD = 40.14 min) on the experiment day. The starting time of the nap was within the range of their normal times. All conditions were started at the same time for each participant.

The environments of the experimental days (temperature, humidity and noise) are shown in Table 1. There were no statistically significant differences between the two conditions.

Sleep structure during the nap

Table 2 shows the sleep structure during the nap. Total sleep time was 12.6 min in the self-awakening condition and 13.0 min in the forced-awakening condition. The data showed that the participants could have enough sleep time in the naps. Slow wave sleep (SWS) and rapid eye movement (REM) sleep did not appear in either condition. There were no significant differences in any variables between the two conditions.

Arterial blood pressure

Figure 1 shows arterial systolic (Fig. 1a) and diastolic

Table 2. Sleep structure during the nap

Sleep variables		Self-awakening	Forced-awakening	*t*	*p* <
Time in bed (min)		18.7 (1.03)	20.0 (0.00)	1.22	n.s.
Sleep latency (min)		4.7 (1.52)	4.7 (1.08)	0.01	n.s.
Total sleep time (min)		12.6 (0.99)	13.0 (1.27)	0.29	n.s.
Sleep stages (min)	Wake	1.4 (0.52)	2.3 (0.79)	1.06	n.s.
	Stage 1	6.6 (1.09)	6.6 (1.04)	0.05	n.s.
	Stage 2	6.1 (1.10)	6.4 (1.17)	0.16	n.s.
	Slow wave sleep	–	–		
	REM	–	–		
Wake epoch (times)		2.0 (0.69)	2.7 (0.58)	0.92	n.s.
Micro arousal (times)		6.1 (0.97)	6.5 (1.68)	0.19	n.s.
Sleep efficiency (%)		68.7 (6.53)	65.2 (6.33)	0.60	n.s.

Parentheses show standard error.

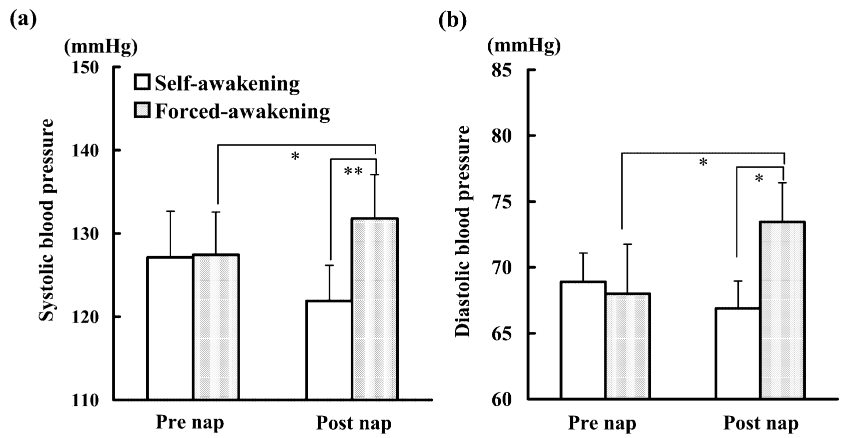


Fig. 1. Systolic (a) and diastolic (b) arterial blood pressure pre- and post- nap.
The error bars in the figures show SEs. *$p<0.05$, **$p<0.01$.

(Fig. 1b) blood pressures pre- and post- nap in both conditions. There was a significant interaction between the condition and the time in systolic [F (1, 8) = 7.57, $p<0.05$] and diastolic [F (1, 8) = 4.94, $p<0.05$] blood pressures. The post-nap blood pressure was significantly higher than at the pre-nap blood pressure [systolic: t (8) = 2.32, $p<0.05$; diastolic: t (8) = 2.86, $p<0.05$] only in the forced-awakening condition. The post-nap blood pressures (systolic and diastolic) were higher in the forced-awakening [t (8) = 3.10, $p<0.05$] than in the self-awakening condition [t (8) = 2.63, $p<0.05$].

Finger blood pressure

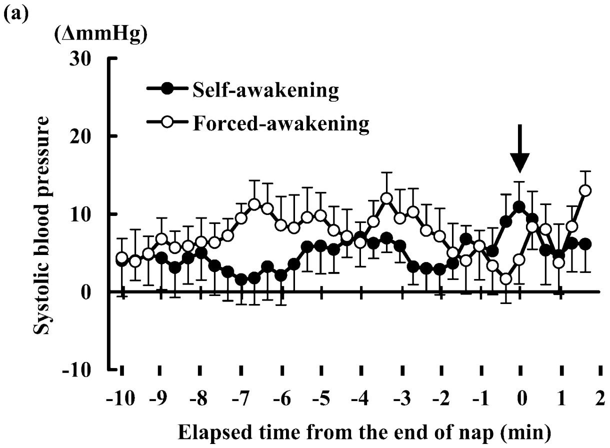
Figure 2 shows the variation in the finger systolic (Fig. 2a) and diastolic (Fig. 2b) blood pressures that is transformed by the baseline obtained from the pre-nap data.

In the systolic blood pressures, there were no significant differences between the two conditions [the main effect of the condition: F (1, 8) = 1.24, p = 0.32; the main effect of the time: F (35, 280) = 1.26, p = 0.31, ε = 0.16; the interaction between the condition and the time: F (35, 280) = 0.92, p = 0.52, ε = 0.28] in the finger systolic blood pressure.

The diastolic blood pressure, however, gradually increased 2 min before self-awakening. This phenomenon was not observed in the forced-awakening condition. There was a significant interaction between the condition and the elapsed time [F (35, 280) = 2.46, $p<0.05$, ε = 0.17]. Post hoc analysis showed this difference near the scheduled wake time ($p<0.05$).

Heart rate

Figure 3 shows the variation in heart rate. In the self-awakening condition, the heart rate did not show any significant changes related to arousal, although a slight



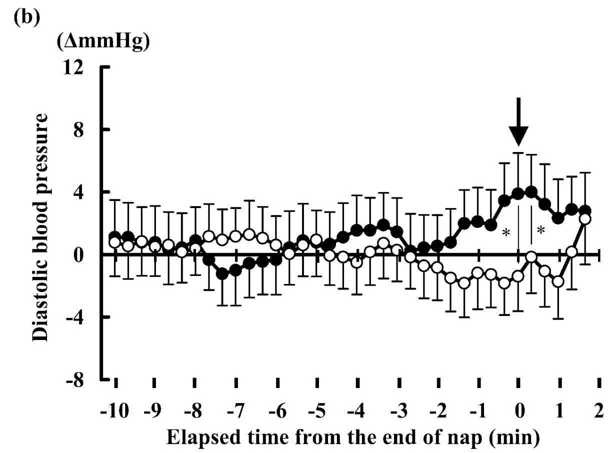


Fig. 2. Systolic (a) and diastolic (b) finger blood pressure during nap.
Each circle in the figure describes the data subtracted (Δ mmHg) from the pre- nap baseline. The arrow in the figure means the end of the nap. The error bars in the figures show SEs. *$p<0.05$.

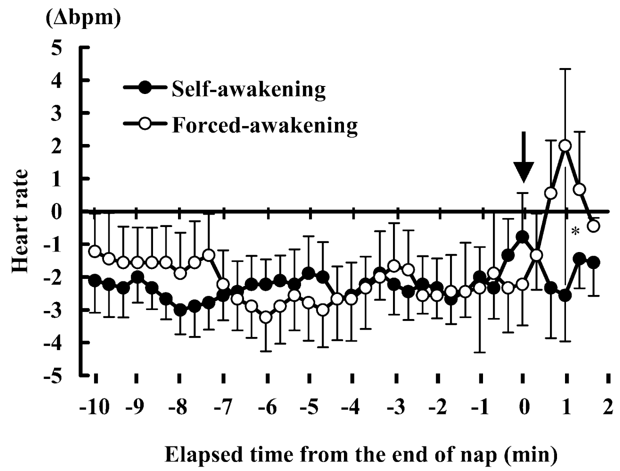


Fig. 3. Heart rate during the nap.
Each circle in the figure describes the data subtracted (Δ bpm) from the pre-nap baseline. The arrow in the figure means the end of the nap. The error bars in the figure show SEs. *$p<0.05$.

increase appeared near the scheduled wake time. In the forced-awakening condition, however, heart rate increased dramatically after the participant awakened. There is a tendency to a significant interaction between the condition and the time [F (35, 280) = 1.75, p = 0.10, ε = 0.22]. Post hoc analysis showed significant differences between both conditions near arousal ($p<0.05$).

Discussion

The present study found that self-awakening prevents acute increases in blood pressure and heart rate which occurred simultaneously with arousal in elderly people. By self-awakening, blood pressure gradually increased before the scheduled arousal time and heart rate did not acutely increase. Blood pressure and heart rate were both increased rapidly by the forced-awakening. There was no significant difference in sleep structure between the self-awakening nap and the forced-awakening nap.

The effect of self-awakening on heart rate is consistent with the finding of the previous study involving young people [21.7 (SD = 1.25) years old][23]. Interestingly, in the previous study, self-awakening affected heart rate, but not blood pressure[23]. To explain this difference between the two age groups, the feedback function of blood pressure and vascular elasticity would have to be considered. Blood pressure is controlled by the feedback function of the autonomic nervous system. The sympathetic nervous system modifies blood pressure and heart rate, and the parasympathetic nervous system monitors bloodstream and blood pressure. The influences of the two systems are usually reciprocal. Because of this control system, blood pressure and heart rate can be adapted to the changes in the external environment. However, as the control system ages, vascular elasticity stiffens and the heart rate becomes unresponsive[31]. As a result, blood pressure can easily become high[18], and heart rate can be insensitive[31].

Some previous studies suggested that the intention to self-awaken might negatively affect night sleep[20, 32]. The time stress caused by a greater sensitivity toward self-awakening may become a cause of disturbed (light) sleep and induce dissatisfaction during night sleep[32]. Nevertheless, there are no significant differences in the sleep structure between the self-awakening and forced-awakening conditions in the present study. The intention to self-awaken may not affect light sleep (sleep stage 1 or 2), but may affect SWS.

The former[23] and present studies showed that some people can self-awaken relatively punctually from a short nap (71% in young people, 90% in elderly people). However, the mechanism of self-awakening is not well known. Recently, Aritake *et al*. (2004)[33] reported that time estimation during sleep is more accurate in sleep stage 2 than SWS or REM[34]. Considering that SWS and REM sleep seldom appear in a short afternoon nap, it is possible that sleep without SWS and REM sleep may contribute to the accurate estimate of the elapsed time during a nap.

Studies have shown that a short nap could be beneficial to manage employee sleepiness in the afternoon[35]. A short nap combined with self-awakening may be the most effective method, given that the majority of the working population is middle-aged or older. Further research should focus on the effect on productivity of a workplace nap with and without self-awakening.

In conclusion, from the present experiments and analysis, self-awakening can prevent the acute increases in blood pressure and heart rate in the elderly. It may also reduce the risk of coronary heart attack that might occur after sudden awakening from an afternoon nap.

Acknowledgement

The authors wish to thank Dr. Masaya Takahashi of the National Institute of Industrial Health, Japan, for his helpful comments on the manuscript.

References

1) Dinges DF (1989) Napping patterns and effects in human adults. In: Sleep and Alertness, Chronobiological, Behavioral, and Medical Aspects of Napping. eds. by Dinges DF, Broughton RJ, 171–204, Raven Press, New York.
2) Broughton RJ (1998) SCN controlled circadian arousal and the afternoon 'nap zoon'. Sleep Res Online **1**, 166–78.
3) Dinges DF (1992) Adult napping and its effects on ability to function. In: Why We Nap. ed. by Stampi C, 118–34, Birkhäuster, Boston.
4) Webb W, Dinges DF (1989) Cultural perspectives on napping and the siesta. In: Sleep and Alertness. eds. by Dinges DF, Broughton RJ, 247–65, Raven Press, New York.
5) Hayashi M, Watanabe M, Hori T (1999) The effects of a 20 min nap in the mid-afternoon on mood, performance and EEG activity. Clin Neurophysiol **110**, 272–9.
6) Takahashi M (2003) The role of prescribed napping in sleep medicine. Sleep Med Rev **7**, 227–35.
7) Takahashi M, Arito H (2000) Maintenance of alertness and performance by a brief nap after lunch under prior sleep deficit. Sleep **23**, 813–9.
8) Tietzel AJ, Lack LC (2002) The recuperative value of brief and ultra-brief naps on alertness and cognitive performance. J Sleep Res **11**, 213–8.
9) Asada T, Motonaga T, Yamagata Z, Uno M, Takahashi K (2000) Associations between retrospectively recalled napping behavior and later development of Alzheimer's disease: association with APOE genotypes. Sleep **23**, 629–34.
10) Stampi C, Mullington J, Rivers M, Campos JP, Broughton R (1990) Ultrashort sleep schedules: sleep architecture and recuperative value of 80, 50 and 20 min naps. In: Sleep '90. ed. by Horne JA, 71–4, Pontenagel, Bochum.
11) Trichopoulos D, Tzonou A, Christopoulos C, Havatzoglou S, Trichopoulou A (1987) Does a siesta protect from coronary heart disease? Lancet **2**, 269–70.
12) Mulcahy D, Wright C, Sparrow J, Cunningham D, Curcher D, Purcell H, Fox L (1993) Heart rate and blood pressure consequences of an afternoon SIESTA (Snooze-Induced Excitation of an Sympathetic Triggered Activity). Am J Cardiol **71**, 611–4.
13) Bursztyn M, Mekler J, Wachtel N, Ben-Ishay D (1994) Siesta and ambulatory blood pressure monitoring. Am J Hypertens **7**, 217–21.
14) Burazeri G, Gofin J, Kark JD (2003) Siesta and mortality in a Mediterranean population: a community study in Jerusalem. Sleep **26**, 578–84.
15) Bursztyn M, Mekler J, Ben-Ishay D (1996) The siesta and ambulatory blood pressure: is waking up the same in the morning and afternoon? J Hum Hypertens **10**, 287–92.
16) Cheng KS, Baker CR, Hamilton G, Hoeks APG, Seifalian AM (2002) Arterial elastic properties and cardiovascular risk/event. Eur J Vasc Endovasc Surg **24**, 383–97.
17) Bursztyn M, Ginsberg G, Hammerman-Rozenberg R, Stessman J (1999) The siesta in the elderly. Arch Intern Med **159**, 1582–6.
18) Bursztyn M, Ginsberg G, Stessman J (2002) The siesta and mortality in the elderly: effect of rest without sleep and daytime sleep duration. Sleep **25**, 187–91.
19) Lavie P, Oksenberg A, Zomer J (1979) It's time, you must wake up now. Percept Mot Skills **13**, 334–9.
20) Bell CR (1980) Awakening from sleep at a pre-set time.

Percept Mot Skills **50**, 503–8.

21) Moorcroft WH, Kayser KH, Griggs AJ (1997) Subjective and objective confirmation of the ability to self-awaken at a self-predetermined time without using external means. Sleep **20**, 40–5.
22) Born J, Hansen K, Marshall L, Malle M, Fehm H (1999) Timing the end of nocturnal sleep. Nature **397**, 29–30.
23) Kaida K, Nakano E, Nittono H, Hayashi M, Hori T (2003) The effects of self-awakening on heart rate activity in a short afternoon nap. Clin Neurophysiol **114**, 1896–901.
24) Webb WB, Campbell SS (1979) The first night effect revisited with age as a variable. Waking Sleeping **3**, 319–24.
25) Jasper HH (1958) The ten-twenty electrode system of the International Federation. Electroencephalogr Clin Neurophysiol **10**, 371–5.
26) Parati G (2000) Continuous finger monirtoring of blood pressure: advantage, problems and perspectives. Blood Pressure Monitoring **5**, 47–9.
27) Hinz A, Seibt R, Scheuch K (2001) Covariation and temporal stability of peripheral and brachial blood pressure responses to mental and static stress. J Psychophysiol **15**, 198–207.
28) Rechtschaffen A, Kales A (1968) In: A Manual of Standardized Terminology, Techniques and Scoring System for Sleep Stage of Human Subjects. eds. by Rechtschaffen A, Kales A, National Institute of Health, Washington DC.
29) Sleep Computing Committee of the Japanese Society of Sleep Research Society, Hori T, Sugita Y, Koga E, Shirakawa S, Inoue K, Uchida S, Kuwahara H, Kousaka M, Kobayashi T, Tsuji Y, Terashima M, Fukuda K, Fukuda N (2001) Proposed supplements and amendments to 'A manual of standardized terminology, techniques and scoring system for sleep stages of human subjects', the Rechtschaffec & Kales (1968) standard. Psychiatry Clin Neurosci **55**, 305–10.
30) American Sleep Disorders Association and Sleep Research Society (1992) EEG arousals: scoring rules and examples. Sleep **15**, 173–84.
31) Gosselin N, Michaud M, Carrier J, Lavigne G, Montplaisir J (2002) Age difference in heart rate changes associated with micro-arousals in humans. Clin Neurophysiol **113**, 1517–21.
32) Hono T, Hiroshige Y, Miyata Y (1991) Nocturnal sleep at a predetermined time in health undergraduate student. Kawasaki Medical Journal **1**, 209–15.
33) Aritake S, Suzuki H, Kuriyama K, Ozaki A, Shibui K, Tan X, Kim K, Kamei Y, Yagaya H, Uchiyama M (2003) Time estimation during nocturnal sleep in human subjects. 1st Congress of Chronobiology, program & abstracts, 60.
34) Danilin VP, Lathash LP (1979) Subjective evaluation of the duration of sleep periods: role of actual time and the representation rate of different EEG stages. Zh Vyssh Nerv Deiat Im I P Pavlova **29**, 502–9.
35) Takahashi M, Nakata A, Haratani T, Ogawa Y, Arito H (2004) Post-lunch nap as a worksite intervention to promote alertness on the job. Ergonomics **47**, 1003–13.