SLEEPINESS

Effects of Afternoon “Siesta” Naps on Sleep, Alertness, Performance, and Circadian Rhythms in the Elderly

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Study objectives: To determine the effects of a 90-minute afternoon nap regimen on nocturnal sleep, circadian rhythms, and evening alertness and performance levels in the healthy elderly.

Design and Setting: Nine healthy elderly subjects (4m, 5f, age range 74y - 87y) each experienced both nap and no-nap conditions in two studies each lasting 17 days (14 at home, 3 in the laboratory). In the nap condition a 90-minute nap was enforced between 13:30 and 15:00 every day, in the no-nap condition daytime napping was prohibited, and activity encouraged in the 13:30—15:00 interval. The order of the two conditions was counterbalanced.

Participants: N/A
Interventions: N/A
Measurements: Diary measures, pencil and paper alertness tests, and wrist actigraphy were used at home. In the 72 hour laboratory studies, these measures were augmented by polysomnographic sleep recording, continuous rectal temperature measurement, a daily evening single trial of a Multiple Sleep Latency Test (MSLT), and computerized tests of mood, activation and performance efficiency.

Results: By the second week in the “at home” study, an average of 58 minutes of sleep was reported per siesta nap; in the laboratory, polysomnography confirmed an average of 57 minutes of sleep per nap. When nap and no-nap conditions were compared, mixed effects on nocturnal sleep were observed. Diary measures indicated no significant difference in nocturnal sleep duration, but a significant increase (of 38 mins.) in 24-hour Total Sleep Time (TST) when nocturnal sleeps and naps were added together (p<0.025). The laboratory study revealed a decrease of 2.4% in nocturnal sleep efficiency in the nap condition (p<0.025), a reduction of nocturnal Total Sleep Time (TST) by 48 mins. in the nap condition (p<0.001) which resulted primarily from significantly earlier waketimes (p<0.005), but no reliable effects on Wake After Sleep Onset (WASO), delta sleep measures, or percent stages 1 & 2. Unlike the diary study, the laboratory study yielded no overall increase in 24-hour TST consequent upon the siesta nap regimen. The only measure of evening alertness or performance to show an improvement was sleep latency in a single-trial evening MSLT (nap: 15.6 mins., no nap: 11.5 mins., p<0.005). No significant change in circadian rhythm parameters was observed.

Conclusions: Healthy seniors were able to adopt a napping regimen involving a 90-minute siesta nap each day between 13:30 and 15:00, achieving about one hour of actual sleep per nap. There were some negative consequences for nocturnal sleep in terms of reduced sleep efficiency and earlier waketimes, but also some positive consequences for objective evening performance and (in the diary study) 24-hour sleep totals. Subjective alertness measures and performance measures showed no reliable effects and circadian phase parameters appeared unchanged.

Key words: Sleep; nap; napping; elderly; human; circadian rhythms; alertness; sleepiness; performance

INTRODUCTION

FROM BOTH CONVENTIONAL WISDOM AND EMPIRICAL EVIDENCE IT IS CLEAR THAT OLDER ADULTS ARE MORE LIKELY TO TAKE AN AFTERNOON NAP THAN ARE YOUNGER ADULTS. In our earlier study of napping in healthy seniors,1 we have found a napping rate of 24.3% for the old, compared to that of 7.9% for the young. This napping rate of about 25% has held up in our archival data when the sample size of seniors has been doubled to more than 100. Part of the reason for increased napping in the elderly may be that older adults are less likely to be prevented by an employer from doing so, but there are also age-related changes in sleep and circadian rhythms that may predispose older people to take an afternoon nap.2,3 In the less healthy elderly there may also be sleep disruptions due to pain and ill-health which may require compensatory napping (see below).

Advice given as part of a sleep hygiene program often prohibits daytime napping.4 Even when expert advice allows for daytime naps, brevity is recommended (e.g., 30 minutes by Ancoli-Israel et al.,5 10—15 minutes by Zarcone [6]) as is both caution and the need for regularity (e.g., by Vitiello7). The implication is that daytime naps are likely to disrupt nocturnal sleep and lead to phase lability in circadian rhythms. While that advice may seem reasonable, there appears to be little hard empirical evidence as to whether an afternoon siesta nap is indeed harmful to an older person’s nocturnal sleep, daytime alertness and performance, or circadian rhythms. The present study sought to provide such evidence.

In both young and old, there is, of course, a biological predisposition to take a short sleep during the afternoon, and most hot climate cultures have a siesta break as part of their normal daily routine.8 The ultra-short sleep/wake studies of Lavie9 and the disentrainment studies of Campbell10 confirm the existence of an open “gate” to sleep in the afternoon hours even in young healthy subjects who do not know the time of day. This is also confirmed in Multiple Sleep Latency Test (MSLT) studies,11 which normally exhibit an M-shaped time of day function with a dip in sleep latency (i.e., increase in sleepiness) at the afternoon test point.

In his review of the timing of self-selected naps, Dinges12...
concluded that the afternoon was by far the most frequent time of day, with a “nap zone” from 14:00 to 16:00 evidenced in a large-scale survey of college students. In an earlier study of adults in general, Tune\textsuperscript{13} also found peak nap start times between 14:00 and 16:00. Our studies of nap patterning have found peak start times of 13:34 for elderly (70y+) males and 14:56 for elderly females using the Social Rhythm Metric,\textsuperscript{14} and a mean nap start time of 14:36 from an overlapping sample of 45 79+\textsubscript{y} elderly subjects assessed by two-week sleep diary.\textsuperscript{15} From a number of different survey and diary studies, Dinges\textsuperscript{12} concluded that the afternoon was by far the most frequent time of day. 14:36 from an overlapping sample of 45 79+\textsubscript{y} elderly sleep need.\textsuperscript{4} This may be necessary if nocturnal sleep is disrupted (found) is the antecedent rather than the consequence, and that a subsequent daytime nap, rather than a consequence of it. Thus, pinging causality in one particular direction, particularly if the nap-turnal sleep is a complicated one. One must be careful in ascribing causality in one particular direction, particularly if the napping is “ad lib.” Poor nocturnal sleep might be the precursor to a subsequent daytime nap, rather than a consequence of it. Thus, when habitual nappers and non-nappers are compared, it is quite possible that the impaired nocturnal sleep of the nappers (if found) is the antecedent rather than the consequence, and that they are “compensatory nappers,” attempting to “top out” their sleep need.\textsuperscript{4} This may be necessary if nocturnal sleep is disrupted by physical or mental ill-health, for example. Such a direction of causality might explain why some studies have found a negative relationship between napping and longevity.\textsuperscript{16} The question of nap efficacy per se can only be properly addressed when a “within-subjects” design is employed with nap vs. no-nap as an independent variable.

Because, even in the elderly, there are strong inter-individual differences in the propensity to nap, and because there is uncertainty as to the direction of causality in the link (if any) between poor nocturnal sleep and the presence of daytime naps, we adopted a design in which all subjects experienced both nap and no-nap conditions in a counterbalanced order. Also, for a nap intervention to be fairly evaluated, we believed that it should be naturally integrated into the daily life of the individual for a matter of weeks rather than days. We thus used two weeks as an acceptable minimum, not being too short to allow full entrainment and not being too long to become overly burdensome to the subjects. This was immediately followed by an intensive 72-hour laboratory evaluation of the subjects’ sleep, circadian rhythms, mood, and performance. The hypotheses to be tested were that compared to a no-nap condition (on a within-subjects basis), 90-minute afternoon siesta nap opportunities would lead to: 1) shorter and more disrupted nocturnal sleep, 2) lower amplitude and more phase labile circadian rhythms, 3) later nocturnal bedtimes, and 4) higher levels of evening alertness and performance.

METHODS

Subjects

Nine healthy paid ($600) volunteer subjects took part in the study (4m, 5f, age range 74y—87y, mean age 78.6y). All passed a strict medical screening that included a complete medical history and physical examination, and a review of current medical records from subjects’ personal physicians. Informed consent was obtained in accord with the University of Pittsburgh IRB. The experiment complied with the Declaration of Helsinki. Some subjects had stable, non-acute chronic medical problems, such as well-controlled hypertension or hypothyroidism, but none showed evidence of unstable medical problems or central nervous system diseases. Medical screening also included a routine laboratory panel (complete blood count, electrolytes, blood glucose, BUN, creatinine, liver function tests, thyroid function tests, urinalysis, and electrocardiogram). All potential subjects were required to be non-obese (Body Mass index < 27 kg/m\textsuperscript{2}), and non-smokers. None complained of any sleep disorder, and none were taking any medication known to affect sleep or circadian rhythms. No subject had a current or past history of psychiatric illness as assessed by the Structured Clinical Interview for DSM-III-R\textsuperscript{17} adapted for DSM-IV. In addition, we administered the Hamilton Rating Scale for Depression (HRSD)\textsuperscript{18} and the Mini-Mental State Examination (MMSE).\textsuperscript{19} All subjects scored < 10 on the HRSD and > 27 on the MMSE. Subjects were required habitually to sleep at least six hour per night. All subjects were also given one screening night of polysomnography (with oximetry and limb movement detection) in the laboratory. No subject had > 15 apneas or hypopneas per hour of sleep or > 15 periodic limb movements with arousals per hour of sleep. There were no exclusion criteria related to habitual napping history. As it happened, napping prevalence prior to the study was low for most (but not all) of the subjects, with five subjects having fewer than two naps per two-week interval as determined in an earlier unrelated sleep diary study (which was carried out a year or more before the present study and which was available for seven of the nine present subjects).

Procedure

Each subject participated in two 17-day studies separated by an 18-day washout. Four subjects experienced the nap condition followed by the no-nap condition, five the reverse order. For the first 14 days of each study they lived at home (apart from the constraints of the protocol) went about their normal daily life. For these 14 days, subjects completed the Pittsburgh Sleep Diary (PghSD)\textsuperscript{15} and Social Rhythm Metric (SRM)\textsuperscript{20} each morning and evening, wore a wrist activity monitor (Actiwacth\textsuperscript{21} on their non-dominant arm, and completed pencil and paper measures of alertness and affect\textsuperscript{21} four times per day. While at home the subjects were encouraged to minimize the disruptions in schedule occasioned by the protocol which started on a Monday morning. It was emphasized to them that the timing of the nocturnal sleep episode on each day was entirely their own choice (thus allowing the average timing of bedtimes and wake times to become dependent variables), but that the siesta nap must occur strictly between 13:30 and 15:00 each and every day of the “nap” condition. They were required to lie on a bed in a darkened room for exactly 90 minutes, setting an alarm clock. They were to attempt to sleep, and were not permitted to get up, even if sleep eluded them. In the no-nap condition, subjects were not allowed to nap during the day. In particular, in the no-nap condition subjects were encouraged to be up and moving about between 13:30 and 15:00.

Subjects were advised to keep the PghSD, SRM and a pen on
their bedside table (following our standard instructions), and to ensure diaries were filled out within an hour of getting up each morning and within an hour of bedtime each evening, as well as after each scheduled nap. They were also encouraged to report on the PghSD if any unscheduled naps inadvertently occurred. The project co-ordinator visited each subject in their home (average of two visits per subject) and was in telephone contact with subjects throughout the study (average of six calls per subject), ensuring compliance, and answering any questions.

Upon entering the University of Pittsburgh Clinical Neuroscience Research Center time isolation laboratories at about 09:00 on the fifteenth day, these measures were augmented by polysomnographic sleep recording, continuous rectal temperature measurement, and computerized tests of mood, activation and performance efficiency, in a laboratory study lasting 72 hours. Objective evening alertness was also measured each day by a single MSLT trial during the evening hours (19:30). In the laboratory, time cues such as clocks and real time TV were available, although there were no windows. Subjects were required to have meals, exercise, showers, etc., according to our standard protocol. Bedtimes were at the subject’s own choice on a nightly basis, and they were also free to wake and get out of bed at the time of their choice ("Whenever you feel you have slept enough and want to get up"). All sleeps (including the siesta naps) were recorded polysomnographically, and subjects were continuously monitored by closed-circuit TV and audio, as well as personal contact with monitoring technicians, in order to ensure protocol compliance (including the avoidance of inadvertent naps).

Core body temperature was measured continuously, using a Yellow Springs Instruments thermistor inserted 10cm into the rectum. The thermometer was connected to a computer via a long umbilical cord allowing freedom of movement throughout the apartment. The computer recorded rectal temperature every minute and alerted technicians to probe slippage. Four times per day there was a computerized mood and performance assessment battery of tests (see below). These tests were scheduled throughout the waking day, avoiding testing times that were within 30 min. from awakening from a nap or a nocturnal sleep. Each testing session took about 30 minutes for the tests which were given in the following order: 1) Nine visual analog scales yielding scores of global vigor (alertness) and global affect (well-being) (2 min.); 2) Purdue pegboard measuring manual dexterity speed separately in left and right hands, the two scores being averaged (5 min.); 3) serial four-choice task requiring key press to an homologous signal on the screen (10 min.); and 4) stop signal task requiring inhibition of a response when a tone was sounded (15 min.). In the evening test session, a fifth test was added: the Mackworth Clock visual vigilance task (20 min.). This task required the detection of an infrequent “double jump” in a pointer clicking around a circle.

The daily procedure allowed subjects to pursue activities, such as hobbies, reading, watching TV, etc., during the day as protocol allowed. Breakfast, lunch, and dinner were specified at usual times using the same procedures as we have developed in our phase shift tolerance studies,22 and exercise and showers limited to a 45-minute interval prior to lunch. Normal daytime illumination levels in the apartment averaged 450 Lux. For the duration of the nap and immediately after dinner time, the lighting in the apartment was dimmed. A dim night-light (<10 lux) was used for the siesta nap, normal incandescent bulbs (<300 lux) for the evening after dinner. During the afternoon (prior to the nap in the nap condition) the subjects had electrodes attached (EEG, EOG, EMG, reference and ground) for polysomnographic recording of the siesta nap and for later recordings of objective sleepiness (see below) in both conditions. Before the final evening performance tests, a single trial of the Multiple Sleep Latency Test was then given (at 19:30) to assess objective evening sleepiness. Standard MSLT procedures were used, including the termination of the test after sleep onset occurred (three consecutive 30-second epochs of any stage of sleep), or after 20 minutes if it did not. The electrodes were then left on the head for later nocturnal sleep recording (but not plugged in) so that when the subject did decide to go to bed, the process could be accomplished without delay. Under both conditions closed circuit TV and personal contact by technicians were used to ensure that unwanted naps did not occur.

Measures Used

For the two-week home studies, the first week of sleep in each 72 hour block were taken as an adaptation sleep and was not analyzed. The following sleep measures were calculated from the polysomnographic record taking Nights 2 and 3 (averaged) and Siesta Naps 2 and 3 (averaged): 1) nap TST; 2) nocturnal TST; 3) grand total TST per 24 hours; 4) nocturnal Time In Bed (TIB); 5) nocturnal diary sleep efficiency (TIB minus estimated sleep latency minus estimated wake after sleep onset (WASO) all divided by TIB and then multiplied by 100; 6) evening global vigor (alertness) from visual analog scales (VAS);7) sleep quality rating from diary VAS.

For the 72 hour laboratory studies, the first night of sleep in each 72 hour block were taken as an adaptation sleep and was not analyzed. The following sleep measures were calculated from the polysomnographic record taking Nights 2 and 3 (averaged) and Siesta Naps 2 and 3 (averaged): 1) nap TST; 2) nocturnal TST; 3) grand total TST per 24 hours; 4) nocturnal TIB; 5) nocturnal sleep efficiency; 6) nocturnal minutes of WASO; 7) nocturnal sleep latency; 8) nocturnal REM latency; 9) nocturnal percent delta; 9) nocturnal automated counts of delta activity using a computer algorithm (delta counts); and 10) nocturnal percent stages 1 and 2. Paired t-tests were used to test for significance.

The single-trial evening (19:30) MSLT latencies from Days 2 and 3 (one day in one cell due to equipment failure) were averaged to yield a measure of objective sleepiness. Following standard procedures, a latency of 20 minutes was assigned to trials in which no sleep occurred. As a measure of subjective sleepiness the global vigor scores from the evening (20:30) mood and performance test sessions (from Days 2 and 3) were averaged. An equivalent measure was then calculated for the non-evening test sessions. In a similar manner, performance measures were averaged from the Days 2 and 3 test sessions (thus reducing practice effects by eliminating the Day 1 data), and comprised: 1) the percentage of signals detected in the Mackworth visual vigilance task; 2) the time taken to do the manual dexterity task (average of left and right hands); 3) the total rate of responding (responses per minute) in the four-choice serial response task; and 4) the number of failures to inhibit a response on the response inhibition task. Performance measures from both evening (20:30), and non-evening (all other) test sessions were calculated separately. In all cases, paired t-tests were used to test for significance.

Each minute-by-minute rectal temperature record for each
subject under each condition was considered as a separate time series with three circadian cycles. A least-squares sinusoid-fitting technique was applied separately by subject and condition to each 72-hour time series. The technique fitted both 24-hour and 12-hour sinusoids to produce a composite curve, and the time of minimum (Tmin) of that fitted curve was used as an estimate of circadian temperature rhythms phase, the half-range (fitted curve maximum value minus fitted curve minimum value all divided by two) as an estimate of amplitude. The cosine fitting procedure also included statistical tests of goodness of fit for the 24-hour component, all fits were highly significant (p<0.001, all cases).

RESULTS

Were the Subjects Able to Nap?

From the diary record it appeared that by the second week of the home study, all nine subjects were able to sleep during their siesta naps. Estimated mean sleep durations (TST) for the week ranged from 40 to 83 mins. (mean: 58 mins., s.d.: 14 mins.). While, strictly speaking, the actigraphic record can only measure inactivity rather than sleep per se, the mean actigraphic trace for nap and no nap conditions also showed indirect evidence for successful napping with a clear trough occurring between 13:30 and 15:00. The ability of subjects to sleep in the siesta nap was confirmed by polysonmography in the laboratory, where mean nap TST for days 2 and 3 of the 72-hour study ranged from 29 to 81 mins. (mean: 57 minutes., s.d.: 18 minutes.). Unintended napping was rare in the no-nap condition of the field study (and completely absent in the laboratory study). From a total of 63 subject-days in the second week of the diary study (no-nap condition) there was a total of only five naps longer than 20 minutes, all from three of the nine subjects. Prior napping history (from well before the start of the study) was available for two of these three subjects, and this indicated habitual napping frequencies of 57% and 79% days, respectively, which was well above the average for the group (about 21%). In the present study, 10 of the 15 unintended naps occurred after 18:00. There were only two unintended naps (from 63 subject-days) in the nap condition.

Was Nocturnal Sleep Disrupted?

As detailed in Table 1, there was less nocturnal sleep obtained in the nap condition vs. the no-nap condition, but this failed to achieve significance (nap: 377 mins., no nap: 397 mins., p>0.15). Wrist actigraphy showed a trend towards a siesta nap-related shortening in the period between nocturnal activity offset and activity onset as defined by a computer algorithm (nap: 350 mins., no-nap: 399 mins., p<0.10). However, in other diary-based measures of sleep disruption (WASO and diary percent sleep efficiency), there were no significant differences or trends between nap and no-nap conditions. Thus, for example, diary sleep efficiency averaged 93.4 in the nap condition, 92.9 in the no-nap condition. This was also true in VAS ratings of nocturnal sleep quality from the diary which averaged 83 and 81, respectively, in nap and no-nap conditions (Table 1). These results were confirmed by the actigraphic trace which indicated no difference in activity counts per hour between (diary determined) bedtime and wake time when nap and no-nap conditions were compared (nap: 256, no-nap: 231, p>0.25). When nap sleeps and nocturnal sleeps (TST) were added together, significantly more 24-hour TST was obtained in the nap condition than in the no nap condition (nap: 435 mins., no-nap: 397 minutes, p<0.025).

In the polyzosnograhyically recorded nocturnal sleeps of the laboratory study (Table 2) there was a statistically reliable difference in nocturnal TST (nap: 318 mins., no-nap: 366 mins., p<0.001), indicating the loss of about 48 minutes of nocturnal sleep. When the average TST from naps and nocturnal sleeps were added together, significantly more 24-hour TST was obtained in the nap condition than in the no nap condition (nap: 435 mins., no-nap: 397 minutes, p<0.025).

Were Circadian Rhythms More Labile and/or of Lower Amplitude?

Figure 1 plots the rectal temperature rhythms (three cycles) under nap and no-nap conditions, averaged across the nine subjects. Apart from the slight dip in temperature evoked by the nap itself (13:30—15:00), there was very little difference between the two curves. This was confirmed when measures of phase (Tmin) and amplitude (half-range) were calculated for each individual under nap and no nap conditions and the resulting parameters

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**Table 1—Sleep diary data from averages of second week of home study under each condition. Given is mean and (s.d.) of nine subjects**

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>NAP TST</th>
<th>NO-NAP</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAP TST</td>
<td>58 (14)</td>
<td>n/a</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>TST*(mins.)</td>
<td>377 (62)</td>
<td>397 (66)</td>
<td>1.50</td>
<td>n.s.</td>
</tr>
<tr>
<td>24h TST</td>
<td>435 (69)</td>
<td>397 (65)</td>
<td>2.78</td>
<td>0.024</td>
</tr>
<tr>
<td>TIB* (mins.)</td>
<td>399 (60)</td>
<td>425 (63)</td>
<td>1.89</td>
<td>0.095</td>
</tr>
<tr>
<td>Sleep eff.*</td>
<td>93.4 (3.1)</td>
<td>92.9 (4.5)</td>
<td>&lt;1</td>
<td>n.s.</td>
</tr>
<tr>
<td>WASO* (mins.)</td>
<td>13 (8)</td>
<td>16 (12)</td>
<td>&lt;1</td>
<td>n.s.</td>
</tr>
<tr>
<td>Sleep quality*</td>
<td>83 (9)</td>
<td>81 (16)</td>
<td>&lt;1</td>
<td>n.s.</td>
</tr>
<tr>
<td>Bedtime*</td>
<td>23:49 (:34)</td>
<td>23:25 (:53)</td>
<td>1.99</td>
<td>0.082</td>
</tr>
<tr>
<td>Wake time*</td>
<td>06:28 (:60)</td>
<td>06:30 (:52)</td>
<td>&lt;1</td>
<td>n.s.</td>
</tr>
</tbody>
</table>

* denotes from nocturnal sleeps only; TST denotes Total Sleep Time; WASO denotes minutes of stage zero (wake) after sleep onset; Sleep eff. denotes sleep efficiency; n.s. denotes p>0.10. All are diary estimates.
Table 2—Polysomnographic variables (average from Nights 2 and 3 of the laboratory study). Given is mean and (s.d.) of nine subjects.

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>NAP</th>
<th>NO-NAP</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAP TST</td>
<td>57</td>
<td>n/a</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>TST* (mins.)</td>
<td>318</td>
<td>366</td>
<td>7.81</td>
<td>0.001</td>
</tr>
<tr>
<td>24h TST</td>
<td>375</td>
<td>366</td>
<td>&lt;1</td>
<td>n.s.</td>
</tr>
<tr>
<td>TIB* (mins.)</td>
<td>428</td>
<td>479</td>
<td>9.04</td>
<td>0.001</td>
</tr>
<tr>
<td>Sleep eff.*</td>
<td>74.5</td>
<td>76.9</td>
<td>2.74</td>
<td>0.025</td>
</tr>
<tr>
<td>WASO*</td>
<td>81</td>
<td>87</td>
<td>1.53</td>
<td>n.s.</td>
</tr>
<tr>
<td>Sleep latency*</td>
<td>29</td>
<td>26</td>
<td>&lt;1</td>
<td>n.s.</td>
</tr>
<tr>
<td>% Stage 1 or 2</td>
<td>73.2</td>
<td>71.6</td>
<td>1.02</td>
<td>n.s.</td>
</tr>
<tr>
<td>REM latency*</td>
<td>57.7</td>
<td>51.5</td>
<td>1.11</td>
<td>n.s.</td>
</tr>
<tr>
<td>% Delta*</td>
<td>4.8</td>
<td>5.2</td>
<td>&lt;1</td>
<td>n.s.</td>
</tr>
<tr>
<td>Delta counts*</td>
<td>15.1</td>
<td>14.4</td>
<td>&lt;1</td>
<td>n.s.</td>
</tr>
<tr>
<td>Bedtime*</td>
<td>23:37</td>
<td>23:21</td>
<td>1.71</td>
<td>n.s.</td>
</tr>
<tr>
<td>Waketime*</td>
<td>06:43</td>
<td>07:19</td>
<td>4.46</td>
<td>0.002</td>
</tr>
<tr>
<td>Time in Bed*</td>
<td>428</td>
<td>479</td>
<td>9.04</td>
<td>0.001</td>
</tr>
</tbody>
</table>

* denotes from nocturnal sleeps only; TST denotes Total Sleep Time; TIB denotes Time In Bed; WASO denotes minutes of stage zero (wake) after sleep onset; Sleep eff. denotes sleep efficiency; Delta counts denotes number of delta waves per minute (detected by an automated zero crossing algorithm applied to all NREM sleep after sleep onset); n.s. denotes p>0.10.

averaged for each group. There was no reliable difference in circadian temperature phase between nap and no-nap conditions (Tmin: nap: 03:19, no nap: 03:32, t<1, p>0.25); neither did the spread of the phase estimates differ by condition (s.d. of Tmin: nap: 67mins., no-nap: 54 mins., F=1.53, n.s.). In amplitude there was a non-significant trend towards a lower amplitude in the nap condition (half range: nap: 0.29 deg. C., no nap: 0.34 deg. C., t=1.93, p=0.09).

Were Nocturnal Bedtimes Later?

From the diary record (Table 1), habitual nocturnal bedtimes averaged 23:49 under the nap condition, 23:25 under the no-nap condition, suggesting a trend (p<0.10) towards a delay in nocturnal bedtime consequent upon the napping regimen. Habitual waketimes were almost identical under the two conditions (06:28 vs. 06:30). In the laboratory (Nights 2 and 3) there was no effect of the siesta nap on bedtime (nap: 23:37, no-nap: 23:21, p>0.10), but a significant advance in waketime in nights following the siesta nap (nap: 06:43, no-nap: 07:19, p<0.005), and thus a shortening of TIB (nap: 428 minutes, no-nap: 479 minutes, p<0.001).

Was Alertness Affected?

Taking the last rating of global vigor from each day of the second week of the home study, there was a remarkable consistency between nap and no-nap conditions in self-rated evening alertness (66 vs. 65, p>0.25) which was also evident (71 vs. 70, p>0.25) in the laboratory data. When the average non-evening alertness ratings was added as a second factor, repeated measures ANOVA revealed no significant time x nap condition interaction (home: F(1,8)=3.26, p>0.10; laboratory: F(1,8)=1, p>0.25); indicating that there was no modification of the time of day effect in alertness consequent upon the siesta nap. However, using the single-trial MSLT (from Days 2 and 3) as a measure of objective evening sleepiness, there appeared to be a beneficial effect of the siesta nap, with mean sleep (MSLT nap) latency increasing from 11.5 to 15.6 mins. (p<0.01) thus indicating a reduction in objective evening sleepiness in the nap condition. A total of 10 subject-trials (out of 17) in the nap condition were associated with no sleep (and were thus assigned a latency of 20 mins.) compared to a total of five subject-trials (out of 18) in the no-nap condition (chi square= 3.44, p=0.06). When non-evening subjective alertness was considered, no significant differences emerged between nap and no-nap conditions in either field conditions (75 vs. 78, p>0.10), or laboratory conditions (76 vs. 74, p>0.25). Combining non-evening and evening as two levels of the factor time, repeated measures ANOVA revealed no significant time x nap condition interaction (home: F(1,8)=3.26, p>0.10; laboratory: F(1,8)<1, p>0.25) indicating that there was no modification of the time of day effect in alertness consequent upon the siesta nap.

Was Performance Affected?

The performance data from the after-dinner trials on Days 2 and 3 of the laboratory study (collected at 20:30) indicated no evidence that the siesta nap had any significant effect (p>0.25 all cases). Visual vigilance hits averaged 64.7% in the nap condition, 64.4% in the no-nap condition; pegboard latency averaged 66.2 seconds in the nap condition, 66.6 seconds in the no-nap condition; four-choice serial response rate averaged 89.5 per minute in the nap condition, 87.8 per minute in the no-nap condition; and commission errors made in the response inhibition task averaged 7.1 in the nap condition, 5.4 in the no-nap condition. A very similar lack of effect was observed when non-evening performance was considered (p>0.25 all cases). Visual vigilance hits averaged 64.7% in the nap condition, 66.2 seconds in the no-nap condition, 88.2 per minute in the nap condition, 87.8 per minute in the no-nap condition; and commission errors made in the response inhibition task averaged 7.1 in the nap condition, 5.4 in the no-nap condition. A significant advance in waketime in nights following the siesta nap (nap: 06:43, no-nap: 07:19, p<0.005), and thus a shortening of TIB (nap: 428 minutes, no-nap: 479 minutes, p<0.001).
Figure 1—Mean rectal temperature, expressed as deviation from the subject's own 72-hour mean, taking 12-minute averages over the 72-hour of the laboratory study. Plotted is the mean of nine subjects +/- one s.e.m. for nap and no-nap conditions.
DISCUSSION

From the mixed findings detailed above, it is quite clear that the taking of a 90 minute siesta nap is unlikely to do very much harm to the nocturnal sleep of healthy elderly people. Thus, should an older person enjoy an afternoon nap (as many do), then he or she should not be discouraged a priori from taking one. Indeed, evidence could be gleaned from this study of a few actual benefits of the napping regimen. Thus, in the diary data there was evidence of a reliable increase in 24-hour TST when nap and nocturnal sleeps were added together (though this did not appear in the laboratory data), and there was a trend towards a delay in bedtime. From the laboratory studies there was evidence that objective evening sleepiness, as measured by a single-trial MSLT, was improved by the siesta nap. However, most of the other findings were either neutral or negative. No significant benefits accrued in evening subjective alertness or performance, and no significant differences appeared in circadian temperature rhythms. In the laboratory study there was a move towards earlier waketimes, slightly lower sleep efficiencies, and shorter nocturnal TST under the nap condition. Since many elderly subjects seek specifically to avoid early morning awakenings and to increase their sleep efficiency, they must be regarded as negative outcomes.

Not addressed in this study is the question of whether the findings would hold true for unhealthy older people. Although the average laboratory nocturnal sleep efficiency of our subjects was (about 75%, which is about one s.d. below the 83% figure usually found for this age group) none were complaining of sleep difficulties or requesting clinical help for their sleep. If their sleep efficiency scores had been markedly lower, and/or had they been actively seeking help for a sleep disorder, it may well be that the bedtime siesta naps might have affected the quality and duration of their nocturnal sleeps more strongly, and thus had measurable adverse consequences on daytime alertness and performance. The question remains an empirical one, however, as it is equally possible that dividing the person’s sleep into two segments might allow the maintenance of better daytime alertness in conditions for which nocturnal sleep is impaired. In our current work we are focussing on patients experiencing unwanted early evening sleepiness in order to see whether these patients might be helped by a napping regimen. Clearly, the positive single-trial evening MSLT results from the present study give hope that the nap intervention might indeed be beneficial.

The lack of any significant findings in regard to the circadian system and the timing of sleep and wakefulness demonstrates the resilience of the circadian timekeeping system and the sleep/wake cycle it underlies, even to something as profound as a move from a monophasic to a (slightly) biphasic sleep pattern. This lack of effect is not altogether surprising, however, as the 90-minute dark (and inactivity) pulse induced by the siesta nap falls at circadian time (CT) 7 (i.e., seven hours after waking) which corresponds to a relatively inactive phase of the human phase response curve (PRC) to a dark pulse when changes in phase would not be expected. Indeed, for the endogenous circadian pacemaker to perform appropriately, a resilience to such nap manipulations is desirable if an overly labile circadian system is to be avoided.

More surprising is the absence of significant evidence regarding the homeostatic determinants of sleep and alertness. This experiment was originally conceived in terms of Borbely’s model involving a rhythmic Process C driven by the circadian pacemaker, and a homeostatic Process S reflecting the build up in sleepiness over the hours since the individual was last asleep. We expected that the siesta nap would serve to dissipate Process S to some extent, thus leading to higher levels of evening alertness and performance, and to later bedtimes. Apart from the decrease in objective sleepiness observed in the evening MSLT trial, and the trend towards a later bedtime in the diary data, the siesta nap appeared to show little evidence of a Process S dissipation. In particular, there was no evidence of a reduction in either hand-scored or automated measures of delta sleep (Table 2). This aspect of the experiment will be the subject of a future study involving spectral analysis. In behavioral measures, there was no evidence of an increase in subjective alertness or objective performance in the evening, with a striking similarity in observed mean values over the two conditions. However, the earlier waketimes observed after naps in the laboratory condition could possibly result from homeostatic changes interacting with rhythmic processes. These findings should, however, be taken in the context of the particular subjects being studied, namely the healthy elderly. It could well be that young subjects would show much more of a Process S effect consequent upon the nap, perhaps because of the increased delta sleep (and enhanced delta power) they show in their sleep relative to the elderly.

CONCLUSIONS

Healthy seniors are able adopt a napping regimen involving a 90-minute siesta nap each day between 13:30 and 15:00 without much difficulty, achieving about one hour of actual sleep per nap. Although there appear to be some negative consequences of the siesta nap for nocturnal sleep, mostly in terms of reduced sleep efficiency and earlier waketimes, there may be some beneficial effects too. Objective measures of evening sleepiness seem to show a significant improvement with napping, and 24-hour sleep totals may increase. Subjective alertness measures and performance measures appear to show no reliable effects, and circadian phase parameters appear to be largely unchanged.

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