Age Modulates the Effects of Sleep Restriction in Women
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**Study Objectives:** To investigate how age influences the effects of 3 nights of sleep restriction in healthy women.

**Design:** After a baseline night, sleep was restricted to 4 hours during 3 consecutive nights. One recovery night followed the sleep restriction.

**Setting:** The sleep-restriction experiments were conducted under standardized conditions with continuous electroencephalographic ambulatory recordings. Before entering the study, the subjects underwent a polysomnographic recording for exclusion of sleep disorder and adaptation to the laboratory environment.

**Participants:** Eleven young women (aged 20-30 years) and 10 older women (aged 55-65 years) were included in the study.

**Intervention:** The subjects were admitted to the sleep laboratory for 5 consecutive nights and days. After 1 baseline night, 3 nights of sleep restriction to 4 hours were performed and were followed by 1 recovery night.

**Results:** Young women were more affected by sleep restriction than were the older women. This was evidenced by more sleep onsets during the Maintenance of Wakefulness Test sessions in the young subjects, who also rated themselves more sleepy than the older women.

**Conclusions:** Age influences the impact of sleep restriction on vigilance in women.

**Keywords:** Sleep restriction, women, aging, vigilance, sleep, wakefulness

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**INTRODUCTION**

**THERE IS INCREASING CONCERN FOR SLEEPINESS-RELATED RISKS IN OUR SOCIETY. THIS PREOCCUPATION IS DUE TO THE RECOGNITION THAT FATIGUE AND sleepiness represent a major risk for human errors leading to accidents and catastrophes.**

There is a scientific debate related to the fact that the modern way of life could lead a majority of people to cut off their sleep time. Indeed, do work hours, social demands, active life style, the network of telecommunications (24-hour television, Internet) contribute to sleep curtailment and chronic restriction of sleep? No actual representative data indicate that our society lacks sleep. Indeed, a recent survey performed in 2000 British adults reported an average sleep duration of 7.04 ± 1.55 hours, which is, according to the authors, not significantly less than 40 years ago.

Recent studies performed in young men have shown that even relatively moderate sleep restriction can impair vigilance in adults, who were unaware of these deficits.

The consequences of acute and chronic sleep restriction have been documented essentially in men. According to epidemiologic data, women tend to sleep more than men. Longer sleep durations have been reported in adult women, either by subjective and objective data. Likewise, women retire to bed earlier and fall asleep earlier than men. However, they also report having more awakenings and poorer sleep quality, particularly during and after the menopause, whereas objective data indicate that their sleep is less disturbed.

Age also modulates sleep duration and sleep quality. It has been proposed that age-related modifications in the circadian pacemaker and in homeostatic sleep mechanisms are involved in the reduced consolidation of sleep and the early morning awakening. An interaction between a decrease in the homeostatic drive for sleep and a reduced strength of the circadian signal are hypothesized to occur in aging people. The effect of age on the response to sleep deprivation is still debated. Indeed, a higher resistance to total and partial sleep deprivation has been evidenced in older men in some, but not all, studies.

A critical issue in sleep-deprivation and sleep-restriction studies concerns the control of the experimental situation itself. Indeed, it is imperative to avoid extra sleep and/or microsleeps outside the scheduled sleep periods. In general, the subjects have been under continuous supervision by the staff. Actigraphic recordings have been performed in some, but not all, studies. However, this method cannot rule out with certitude short sleep episodes. The only effective method consists of continuous electroencephalographic (EEG) recordings. Surprisingly, very few sleep-restriction studies have been performed while the EEG of the subjects was continuously recorded.

The aim of the present study was to assess the impact of age on the effect of sleep restriction on vigilance in women. In this study, 10 young and 10 older women had their sleep restricted to 4 hours during 3 consecutive nights. The sleep-restriction nights were preceded by 1 baseline recording and followed by 1 recovery night. Continuous ambulatory EEG recordings were performed during the experiment to monitor the wake and the sleep.

**METHODS**

**Subjects**

Eleven young and 10 aged, healthy, nonsmoking women were enrolled in the study after a selection procedure. The 11 young women were 20 to 30 years old (mean ± SD: 23.2 ± 3.2 ) and were not taking birth control medication. The 10 aged women were...
postmenopausal women aged 55 to 65 years (mean ± SD: 60.0 ± 3.8) who were not treated by hormone replacement therapy: 7 women had never used hormonal replacement therapy, and 3 women had stopped their treatment for at least 3 months. All participants gave written informed consent and received a financial compensation for their participation to the study. The protocol was approved by the Ethics Committee of the CHU A. Vésale. The subjects were free of neurologic, psychiatric, cardiac, and endocrine disease, as determined by medical history, physical examination, blood analysis, and electrocardiogram. Long and short sleepers, as well as extreme chronotypes, were excluded. The subjects had no sleep complaint and were not snoring. The presence of a sleep disorder was excluded on the basis of interview, questionnaires (Pittsburgh Sleep Quality Index, Epworth Sleepiness Scale, Horne and Ostberg scale) and 1 night of polysomnography performed before the inclusion in the study. The sleep apnea and hypopnea index and the periodic leg movement index had to be less than 5 per hour. The volunteers were not drinking alcohol on a regular basis. Their consumption of xanthine beverages had to be less than 5 units per day. The young women were studied during the first part of their menstrual cycle.

PROCEDURE

Before inclusion in the study, the volunteers underwent physical examination, blood test, and urine drug screen. One night of polysomnography was performed in the women who had fulfilled all selection criteria. Two women (55 and 56 years of age) were excluded: 1 because of a long period of wake (2 hours) during the night and the other because of a periodic limb movement disorder. The selected 21 subjects were asked to follow a regular sleep-wake schedule (11:00 PM-7:00 AM) during the 2 weeks prior to the study. In this respect, they kept daily sleep logs and wore wrist actigraphs.

The volunteers spent 5 days in the sleep laboratory. The first night was a baseline night (11:00 PM-7:00 AM). During the next 3 nights, their sleep was restricted to 4 hours (1:00 AM-5:00 AM). The fifth night was a recovery night (11:00 PM-7:00 AM). Continuous EEG and electrooculographic recordings were performed with an ambulatory device (Medatec Pamela) except between 9:00 AM and 1:00 PM, during which time the subjects could take a shower or were under close supervision of the experimenter performing various cognitive tasks. To avoid boredom, which could interfere with their motivation, the subjects were allowed to leave the unit between 5:00 PM and 8:00 PM with continuous ambulatory EEG recordings and were not allowed to drive. During the whole study, consumption of alcohol and xanthine derivatives (coffee, tea, chocolate) were prohibited. The subjects received standard hospital meals with a maximum of 2500 calories per day and a comparable proportion of nutrients (protein, fats, carbohydrates) across days and sessions. Controlled snacks and drinks were available during the restriction nights. Two volunteers were studied simultaneously but in individual bedrooms. The EEG recordings were controlled every day to detect potential sleep episodes at inappropriate time. In this respect, 1 young subject was excluded from the study because of long sleep episodes (258 minutes in total) outside the permitted hours. All recordings were analyzed according to conventional criteria.

Neurobehavioral Evaluations

The ability to sustain wakefulness was assessed by performing the Maintenance of Wakefulness Test (MWT). This test was performed during 20 minutes 2 times per day at 8:30 AM and 1:30 PM during baseline and sleep restriction. After the recovery night, it was performed only at 8:30 AM. During the test, the subjects were comfortably installed in a chair in a dimly lighted room and instructed to remain awake while polysomnographic recordings were performed. The test was interrupted at the onset of sleep (stage 1), and the subject was immediately awakened. In the absence of sleep, the test ended after 20 minutes.

The subjects self-evaluated their sleepiness using the Stanford Sleepiness Scale everyday at 7:00 AM, 9:00 am, 1:00 pm, and 5:00 pm.

The neurobehavioral assessments also included a psychomotor vigilance task (PVT), which is a sustained-attention reaction time task. It measures simple reaction time to a visual stimulus presented, on average, 10 times per minute for a duration of 10 minutes. The PVT tests were performed at 9:00 AM, 1:00 pm, and 5:00 PM on the baseline and after the third sleep-restriction night, at 9:00 AM and 1:00 PM on the first and second days of sleep restriction, and at 9:00 AM on the recovery day. The dependent measures were the mean reaction time and the number of lapses.

Cognitive evaluations, including selective attention, abstraction, and long-term and working memory were also performed in the morning and the afternoon after the PVT and MWT; these results will be presented elsewhere.

Statistics

The data were analyzed using mixed-factor analysis of variance. The between factor was the factor “Age” with 2 levels: young and aged. The within factors, according to the various tests, were factor “Condition” for the day of the study with 2 or 5 levels (baseline, restriction 1, restriction 2, restriction 3, and recovery) and factor “session” for the time of the day. The Greenhouse-Geisser test was applied when the results at the Mauchly test for sphericity for homogeneity of covariance were significant. The Bonferroni pairwise comparisons were used for the levels of Restriction. In addition student t tests were performed when appropriate. All computations were done with the SPSS statistical software (SPSS, Inc., Chicago, Ill.).

RESULTS

Sleep

During the 2 weeks preceding the study, the 2 groups of women had similar total sleep times, as estimated by actigraphic recordings: in the young women it was 7.9 ± 0.935 hours, and in the aged women it was 8.1 ± 0.838 ( student t test: P = 0.7). Sleep variables in the 2 groups of women during baseline, sleep restriction, and recovery are listed in Table 1.

There was no significant age effect for any sleep variable, despite a tendency toward an increase in stage 1 and a decrease in stage 3/4 in the aged women. A condition effect was observed for all sleep variables. Thus, stage 1 sleep decreased during sleep restriction and recovery in the 2 groups: pairwise comparisons showed a significant difference between baseline night and second night of restriction, third night of restriction, and recovery
Comparisons showed a significant difference between baseline and all restriction nights. A similar pattern was found for stage 2 sleep, with a significant decrease during restriction and recovery. Pairwise comparisons indicated a significant difference between baseline and all subsequent nights and between the third night of sleep restriction and the recovery night.

The percentages of stages 3 and 4 sleep significantly increased during sleep restriction and recovery in both groups. The pairwise comparisons showed a significant difference between baseline night and all restriction nights and between recovery night and all restriction nights. There was a small increase in the minutes of stages 3 and 4 sleep during the restriction and a significant increase during the recovery night. This increase tended to be more marked in the young than in the older women. The evolution of the minutes of stages 3 and 4 sleep is illustrated in Figure 1.

Concerning rapid eye movement (REM) sleep, a condition effect was evidenced, as was an interaction between age and condition. In the young women, there was a significant decrease in REM percentage during the first night of restriction compared with the baseline night and a significant increase during the recovery night in comparison with the restriction nights. In the aged women, the pattern of evolution tended to be different. Indeed, a rebound in REM sleep percentage was observed during the second and third nights of restriction, but this difference was not significant. The minutes of REM sleep decreased during the restriction nights in both groups, and a rebound was found during the recovery night. There was a condition effect for sleep efficiency that was higher during restriction and recovery, as compared with baseline.

The analysis of the continuous EEG recordings allowed the detection of sleep episodes outside the permitted hours. Five young women and 4 aged women did not present any sleep outside the permitted hours. During the first day of sleep restriction, no subject slept outside the permitted hours. Episodes of sleep were detected during the second day in 2 young women and in 3 aged. During the third day, extra sleep episodes were found in 4 young and 3 aged women. In the young women, the sleep episodes occurred in the early morning between 5:00 AM and 7:30 AM; the episode duration was between 3 minutes and 30 minutes. In the aged women, the extra sleep episodes were observed mostly in the evening between 10:40 PM and 12:30 AM and also in the early morning between 5:00 AM and 6:30 AM. The duration of these episodes was shorter in the aged women.

Table 1—Sleep Variables During Baseline, Sleep Restriction, and Recovery in the 2 Groups of Women

<table>
<thead>
<tr>
<th>Sleep variables</th>
<th>Group</th>
<th>Baseline</th>
<th>Restrict 1</th>
<th>Restrict 2</th>
<th>Restrict 3</th>
<th>Recovery</th>
<th>Analysis of variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 1</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage, %</td>
<td>Young</td>
<td>4.1 ± 2.5</td>
<td>3.5 ± 2.3</td>
<td>2.3 ± 2.1</td>
<td>2.4 ± 1.6</td>
<td>2.3 ± 0.7</td>
<td>Condition: P &lt; .001</td>
</tr>
<tr>
<td></td>
<td>Aged</td>
<td>7.6 ± 5.0</td>
<td>4.9 ± 5.6</td>
<td>2.7 ± 1.4</td>
<td>2.1 ± 1.6</td>
<td>3.4 ± 2.3</td>
<td></td>
</tr>
<tr>
<td>Minutes</td>
<td>Young</td>
<td>16.9 ± 10.6</td>
<td>7.9 ± 5.3</td>
<td>5.1 ± 4.7</td>
<td>5.2 ± 3.8</td>
<td>10.2 ± 3.7</td>
<td>Condition: P &lt; .001</td>
</tr>
<tr>
<td></td>
<td>Aged</td>
<td>32.6 ± 13.1</td>
<td>13.3 ± 7.9</td>
<td>9.7 ± 8.7</td>
<td>7.2 ± 6</td>
<td>20 ± 14</td>
<td></td>
</tr>
<tr>
<td>Stage 2</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage, %</td>
<td>Young</td>
<td>51.3 ± 8.8</td>
<td>36.3 ± 8.8</td>
<td>34.8 ± 9.3</td>
<td>32.1 ± 6.4</td>
<td>40.2 ± 5.7</td>
<td>Condition: P &lt; .001</td>
</tr>
<tr>
<td></td>
<td>Aged</td>
<td>50.9 ± 9.9</td>
<td>40.7 ± 13.2</td>
<td>34.7 ± 15.1</td>
<td>32.0 ± 13.5</td>
<td>42.0 ± 11.6</td>
<td></td>
</tr>
<tr>
<td>Minutes</td>
<td>Young</td>
<td>215 ± 27</td>
<td>82.5 ± 19.8</td>
<td>81.4 ± 22.4</td>
<td>76 ± 15.6</td>
<td>187 ± 27.1</td>
<td>Condition: P &lt; .001</td>
</tr>
<tr>
<td></td>
<td>Aged</td>
<td>244 ± 32.7</td>
<td>105 ± 33.7</td>
<td>111 ± 27.9</td>
<td>111 ± 33.5</td>
<td>228 ± 60</td>
<td></td>
</tr>
<tr>
<td>Stage 3+4</td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Percentage, %</td>
<td>Young</td>
<td>28.2 ± 10.1</td>
<td>46.2 ± 9.8</td>
<td>48.9 ± 10.4</td>
<td>50.4 ± 6.7</td>
<td>34 ± 4.6</td>
<td>Condition: P &lt; .001</td>
</tr>
<tr>
<td></td>
<td>Aged</td>
<td>21.7 ± 13.9</td>
<td>39.0 ± 18.1</td>
<td>40.1 ± 18.5</td>
<td>44 ± 17.7</td>
<td>29.9 ± 13.4</td>
<td></td>
</tr>
<tr>
<td>Minutes</td>
<td>Young</td>
<td>106 ± 42</td>
<td>96.9 ± 29.1</td>
<td>115 ± 25.4</td>
<td>118 ± 15.8</td>
<td>159 ± 23.4</td>
<td>Condition: P &lt; .001</td>
</tr>
<tr>
<td></td>
<td>Aged</td>
<td>95 ± 64.1</td>
<td>89 ± 40.6</td>
<td>94 ± 49.4</td>
<td>102 ± 46</td>
<td>133 ± 67.9</td>
<td></td>
</tr>
<tr>
<td>Stage REM</td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Percentage, %</td>
<td>Young</td>
<td>19.7 ± 3.9</td>
<td>13.9 ± 3.7</td>
<td>13.9 ± 8.2</td>
<td>14.9 ± 5.6</td>
<td>23.5 ± 5.8</td>
<td>Condition: P &lt; .003</td>
</tr>
<tr>
<td></td>
<td>Aged</td>
<td>19.9 ± 6.2</td>
<td>15.3 ± 10.2</td>
<td>22.5 ± 5.9</td>
<td>21.9 ± 7.8</td>
<td>24.7 ± 5.2</td>
<td>Interaction age condition†</td>
</tr>
<tr>
<td>Minutes</td>
<td>Young</td>
<td>83.7 ± 20</td>
<td>31.5 ± 8.5</td>
<td>32.1 ± 19.2</td>
<td>34.2 ± 13.4</td>
<td>109 ± 26.8</td>
<td>Interaction age condition†</td>
</tr>
<tr>
<td></td>
<td>Aged</td>
<td>85 ± 19</td>
<td>42 ± 17.7</td>
<td>48.8 ± 13.6</td>
<td>47.8 ± 17.1</td>
<td>112.7 ± 22.8</td>
<td></td>
</tr>
<tr>
<td>Efficiency, %</td>
<td>Young</td>
<td>87.6 ± 6.8</td>
<td>94.6 ± 3.6</td>
<td>96.5 ± 2.6</td>
<td>96.4 ± 2.1</td>
<td>96.9 ± 1.6</td>
<td>Condition: P &lt; .001</td>
</tr>
<tr>
<td></td>
<td>Aged</td>
<td>84.2 ± 8.6</td>
<td>91.9 ± 4.3</td>
<td>95.8 ± 1.8</td>
<td>96.2 ± 2.2</td>
<td>92.4 ± 3.9</td>
<td></td>
</tr>
</tbody>
</table>

Restrict refers to restriction; B, baseline night; R1, first night of restriction; R2, second night of restriction; R3, third night of restriction; Rec, recovery night.

*P < .01
†P < .05
The data are presented as mean ± SD.

Figure 1—Evolution of minutes of stages 3 and 4 (mean ± SD) in young (●) and aged women (▲)
sleep episodes varied between 2 and 22 minutes. Before the recovery night, 2 aged women had a short sleep before 11:00 PM (21 minutes at 9:23 PM and 10 minutes at 8:10 PM). There was no significant difference between the 2 groups in the number of sleep episodes and their duration: 10.4 ± 8.4 minutes in the aged women and 12.2 ± 10.2 minutes in the young women (student t test: P = .73). However, a tendency to have more sleep in the early morning hours was found in the young subjects.

Maintenance of Wakefulness Test

The results at the MWT are listed in Table 2. During baseline, no sleep onset was detected. During sleep restriction, 9 young women (90%) fell asleep, whereas only 2 older women (22%) had at least 1 sleep episode. There were 30 onsets of sleep in the young women (mean ± SD: 3.3 ± 3.08), whereas only 3 onsets were detected in the aged women (mean ± SD: 0.33 ± 0.5) (student t test: P = .01). The number of sleep onsets increased in the young women from the second day of restriction.

Stanford Sleepiness Scale

The evolution of the scores at the Stanford Sleepiness Scale during baseline, sleep restriction, and recovery in the 2 groups at 9:00 AM, 1:00 PM and 5:00 PM are presented in Figure 2. The 3-factor mixed analysis of variance (Age × 2; Conditions × 4; Hours × 3) revealed a significant main effect for Condition (P < .001) with a significant age × condition interaction (P < .001), indicating that the young women only felt more sleepy during sleep restriction. Such an effect was not found in the older women. Multiples comparisons indicated that the Condition main effect was evident for the second and third days of restriction (P < .01).

Psychomotor Vigilance Test

Reaction Time

The reaction times (mean ± SD) at 9:00 AM 1:00 pm, and 5:00 PM in the 2 groups are illustrated in Figure 3. The 3-factor mixed analysis of variance (Condition × 4, Age, Session) showed a significant main effect for Condition (P < .05). No age effect was detected, but there was a condition × age interaction (P < .05). Multiple comparisons indicated an increase in the number of lapses after the second and the third nights of restriction (P < .05) in the young women and only after the first restriction night in the old women (P < .05).

Table 2—Mean Number of Sleep Onsets and Mean Sleep-Onset Latencies on the Maintenance of Wakefulness Test at 8:30 AM and 1:30 PM in the 2 Groups of Women During Baseline, Sleep Restriction, and Recovery

<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>B</th>
<th>SR1</th>
<th>SR1</th>
<th>SR2</th>
<th>SR2</th>
<th>SR3</th>
<th>SR3</th>
<th>R</th>
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</thead>
<tbody>
<tr>
<td>Young</td>
<td></td>
<td></td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>no.</td>
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<td></td>
</tr>
<tr>
<td>Sleep-onset latency, min*</td>
<td>-</td>
<td>-</td>
<td>12 ± 5.3</td>
<td>9.8 ± 8.4</td>
<td>7.4 ± 6.2</td>
<td>6.6 ± 11.3</td>
<td>5.1</td>
<td>3.4</td>
<td>6</td>
</tr>
<tr>
<td>Aged</td>
<td></td>
<td></td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>no.</td>
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<td></td>
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</tr>
<tr>
<td>Sleep-onset latency, min</td>
<td>-</td>
<td>-</td>
<td>3.3</td>
<td>-</td>
<td>-</td>
<td>10</td>
<td>-</td>
<td>15.8</td>
<td>-</td>
</tr>
</tbody>
</table>

B refers to baseline; SR1, first night of sleep restriction; SR2, second night of sleep restriction; SR3, third night of sleep restriction; R, recovery night.

*Data are presented as mean ± SD.
comparable in both groups. Similar data have been obtained in recordings performed during the 2 weeks preceding the study was subjects. Indeed, sleep duration estimated from the actigraphic
use in this study was less sensitive to detect differences between healthy women. It is conceivable that the classical visual scoring
our expectations,
concerns the evolution of sleepiness during the sleep restriction: with increasing age, though the presence of a decreased need for sleep with
The effects of the 3 nights of sleep restricted to 4 hours per night were more pronounced in young women than in older women, at the MWT, the Stanford Sleepiness Scale, and the Psychomo-
tor Vigilance Test, when performed in the morning and the early afternoon. Indeed, during sleep restriction, young women fell
 asleep at the MWT more frequently, their scores at the Stanford Sleepiness Scale were higher, and they had longer reaction times on the Psychomotor Vigilance Test. There was no significant dif-
ference between the 2 groups for the minutes and percentages of sleep stages during baseline. High amounts of slow-wave sleep were observed in the young healthy women, who were nonsmok-
ers and not taking any drugs or oral contraceptives. Contrary to our expectations, slow-wave sleep was well preserved in the aged
healthy women. It is conceivable that the classical visual scoring used in this study was less sensitive to detect differences between young and aged subject, as compared with spectral analysis, which has consistently shown a decrease in slow-wave activity with increasing age. The fact that aged women better tolerated the sleep restriction than young women cannot be attributed to a greater decrease in sleep duration during restriction in the young subjects. Indeed, sleep duration estimated from the actigraphic recordings performed during the 2 weeks preceding the study was comparable in both groups. Similar data have been obtained in men in total sleep-deprivation studies and in a sleep-fragmentation study. Nevertheless, this age effect could have been less obvious if vigilance tests had also been performed during the evening and the night. Indeed, young subjects are more evening-oriented than are older subjects. This observation was supported by the fact that extra sleep episodes tended to be more frequent in the morning in the young subjects and in the evening in the aged subjects. To our knowledge, this is the first report on an age-related effect of sleep restriction in women. The decreased sensitivity to sleep restriction with age could reflect a decreased need for sleep with age, though the presence of a decreased need for sleep with age is still a matter of controversy. Another interesting aspect concerns the evolution of sleepiness during the sleep restriction: in the young women, there was a progressive increase in sleep-
ness during the successive days of sleep restriction, paralleling the development of a sleep debt, while, in the older women, a kind of adaptation to the restriction was evidenced. This difference in the evolution of the deficits due to sleep restriction could also be another argument for a decreased sleep need with age. Furthermore, at variance with results from young men in another study, young women rated themselves more sleepy during the sleep restriction, whereas the older women did not. This subjective evaluation was corroborated by the MWT results.

From a methodologic point of view, our study underlines the importance of continuous EEG recording during sleep-restriction experiments: indeed, despite the fact that the subjects were aware that all sleep episodes would be detectable, some of them could not refrain from sleeping during forbidden periods. Most subjects were totally unaware of these sleep episodes. This tendency for extra sleep increased during the successive days of restriction. The patterns of occurrence of these sleep episodes was slightly different in the 2 groups: the young women tended to have more sleep early in the morning, reflecting their circadian evolution of sleepiness. The absence of sleep while the subjects were outside the unit indicate that this procedure did not interfere with the experiment. One young women was excluded during the study because of extended sleep episodes outside the permitted hours, despite the instructions she received and the fact that she was continuously monitored. Thus, without continuous monitoring of EEG activity, it is impossible to prove that there is no sleep at all outside the scheduled periods of sleep. Furthermore, it is possible that the occurrence of unscheduled sleep, even of very short duration, could explain the interindividual variability in the response to sleep deprivation and sleep restriction in the studies in which continuous EEG recordings have not been performed. Further studies are needed to answer this question.

Our data also indicate that the MWT is a sensitive tool to explore and to monitor the deficits in the ability to maintain wakefulness during sleep-curtailment experiments. Indeed, during baseline, no sleep onset was detected, and sleep onsets increased across the successive days of sleep restriction.

ACKNOWLEDGMENTS

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