Original Article

Napping and weekend catchup sleep do not fully compensate for high rates of sleep debt and short sleep at a population level (in a representative nationwide sample of 12,637 adults)

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ABSTRACT

Introduction: Short total sleep time (TST < 6 h) is a strong major health determinant that correlates with numerous metabolic, cardiovascular and mental comorbidities, as well as accidents. Our aim was to better understand, at a population level, how adults adapt their TST during the week, and how short sleepers and those with sleep debt and sleep restriction use napping or catching up on sleep during weekends (ie, sleep debt compensation by sleeping longer), which may prevent these comorbidities.

Methods: A large representative sample of 12,367 subjects (18–75 years old) responded by phone to questions about sleep on a national recurrent health poll (Health Barometer; Santé Publique France 2017) assessing sleep schedules (TST) at night, when napping, and over the course of a 24-h period while using a sleep log on workdays and weekends. Retained items were: (1) short sleep (TST < 6 h/24 h); (2) chronic insomnia (international classification of sleep disorders third edition, ICSD-3 criteria); (3) sleep debt (self-reported ideal TST – TST > 60 min, severe > 90 min); and (4) sleep restriction (weekend TST – workday TST = 1–2 h, severe > 2 h).

Results: Average TST/24 h was 6h42 (±3 min) on weekdays and 7h26 (±3 min) during weekends. In addition, 35.9% (±1.0%) of the subjects were short sleepers, 27.7% (±1.0%) had sleep debt (18.8% (±0.9%) severe), and 17.4% (±0.9%) showed sleep restriction (14.4% (±0.8%) severe). Moreover, 27.4% (±0.9%) napped at least once per week on weekdays (average: 8.3 min (±0.5 min)) and 32.2% (±1.0%) on weekend days (13.7 min (±0.7 min)). Of the 24.2% (±0.9%) of subjects with severe sleep debt (>90 min), only 18.2% (±1.6%) balanced their sleep debt by catching up on sleep on weekends (14.9% (±0.8%) of men and 21.5% (±0.9%) of women), and 7.4% (±1.2%) of these subjects balanced their sleep debt by napping (7.8% (±0.5%) of men and 6.6% (±0.4%) of women). The remaining 75.8% (±5.4%) did not do anything to balance their severe sleep debt during the week.

Discussion and conclusions: Short sleep, sleep debt, and sleep restriction during weekdays affected about one third of adults in our study group. Napping and weekend catch-up sleep only compensated for severe sleep debt in one in four subjects.

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1. Introduction

Doctors frequently recommend a good night of sleep as a prevention strategy to their patients, and consider this to be as efficient as participating in a sport on a regular basis or maintaining healthy nutrition [1,2]. Sleep is indeed critical to the metabolic and thermodynamic balance of the body, as well as immunity, injury reparation and growth; furthermore, sleep can even affect memory, idea selection, and mood regulation [3–7].

However, we still do not understand in a concise manner the individual need for sleep and its relation to age, activity level and environmental cues. For example, do adults necessarily require an
optimum of 7–8 h of sleep, or is it feasible to manage on less than 6 h of sleep? Furthermore, is one single sleep event in a day sufficient, or can we manage on several episodes of sleep? Likewise, is it acceptable to nap, and if so for how long? Indeed, the “normative” values of sleep and the risk (or not) of developing comorbidities continue to be highly debated by international public health authorities and sleep specialists [1,2,4,8–15].

Ten years ago, a national survey of 24,671 French adults observed an average TST of 7 h13 in adults, 17.9% of whom were “short sleepers” with an average TST of < 6 h and 2.7% reporting a sleep duration of greater than 10 h [8]. Many studies in different countries have shown that despite a regular average TST in the adult population of around 7 h, the percentage of “short sleepers” sleeping less than 6 h has consistently increased for more than a decade, particularly among young adults and professionals, with an average response rate of 25–33% in interviewed subjects [16,20,21]. This is clearly related to modern time management in accordance with work schedules, transportation time, and the increasing time devoted to new technologies such as smartphones, internet and screen use before bedtime, especially among young adults and professionals [16–19].

Moreover, many contributing studies demonstrate that sleeping less than 6 h in a 24-h period is associated with an increased mortality, risk of metabolic and cardiovascular diseases (i.e., obesity, type 2 diabetes, stroke, hypertension, etc.), and accidents [9–15]. Notably, sleeping more than 9–10 h in adults is also associated with an increase in mortality and morbidity risks [9–11,13–15]. However, this mostly concerns the elderly, and the most common hypothesis to explain this association is chronic fatigue disease, which provokes napping and staying in bed, as compared to controls [8].

In order to balance the deleterious effect of short sleep in their daily lives, many people attempt to catch up on sleep by taking short naps whenever possible, or trying to “catch-up sleep” on weekends [24,25]. Researchers are examining these strategies in the laboratory and under real life conditions, from napping to catch-up sleep on weekends to sleep extension [24–31]. Napping is highly recommended at the workplace for shift workers, and as a means to prevent accidents in long-haul drivers [24]. However, the recommended length and frequency of napping must be made more precise. Sleep extension (i.e., sleeping more than usual) is a technique proposed in anticipation of sports performances or sleep deficit that may come in the following nights [29–31]. Finally, various studies have also tested the efficacy of “catch-up sleep”, i.e., sleeping as much as possible on weekends in order to prevent the consequences of sleep debt during weekdays [26,32]. Nevertheless, currently how people manage their curtailed sleep in real life, and there are currently no specific or personalized recommendations remains unknown. Therefore, the goal of this epidemiological survey was to specifically describe the 24 h sleep and nap rhythms of subjects in the general population, and to provide an overview of the magnitude of short sleep, as well as the weekday and weekend strategies of people, depending on their age and other factors.

2. Methods

2.1. Data sources

The Health Barometer 2017 was a cross-sectional phone survey on health risk behaviors, and the knowledge and perceptions of those risks, conducted by the French national public health agency on a randomized representative sample of metropolitan French-speaking adults (18–75 years old). The recruitment was performed via a randomized selection of home and mobile phone numbers, by specialized interviewers assisted with a computerized questionnaire, between January 5 and July 18, 2017. The participation rate was 48.5%, and the average length of a single interview was 31 min.

This survey used a two-stage random sample, by sampling telephone numbers and sampling a single respondent within the list of eligible persons using one telephone number. First, two separate samples of landline and cellular telephone numbers were generated using random digit dialing based on number prefixes corresponding to the blocks of numbers assigned by the French telecommunications regulator. Then, for households in the landline sample, one person was randomly selected, using the Kish method [33], among the eligible persons living in the household (18–75 years old, and speaking French); in the cellular telephone sample, the selected interviewee was the one who answered the phone. We did not replace households if they refused to participate, or if the individual selected was unreachable. Thus, we made a special effort to successfully reach households and increase the response rate. Since randomly selected telephone numbers may or may not be listed in an open telephone directory, a national reverse directory was used to determine whether an account name and street address was associated with each number to be called. In the event of a listed name and address, we sent an information letter to that person briefly explaining the study, who was conducting it, and expressing the importance of participation.

Whenever a selected individual was reached but unavailable, an appointment was made. We made at least 40 attempts to complete an interview with every sampled number. The calls were staggered over different times of day and days of the week, in order to maximize the chances of making contact with a potential respondent. Individuals unwilling to participate at first were re-contacted by specialized interviewers, who tried again to recruit them. All collected data were anonymous and self-reported. The survey was approved by the National Data Protection Authority. Each interviewed subject signed an informed consent confirming the anonymous analysis of the questionnaires.

In total, 25,319 subjects participated in the global survey. The goals, ethical rules and technical aspects of the survey were previously detailed in a methods paper [34]. A specific group of questions on sleep was randomly proposed to half of the subjects (n = 12,637), who were representative of metropolitan French-speaking adults (18–75 years old). To interview night-shift workers about sleep, we used specific questionnaires that took their irregular schedules into account (n = 602; 4.8% of the group).

2.2. Sleep values

While interviewing subjects, and only at this single occasion, we asked questions on several sleep log items such as “Typically, on weekdays, at what time do you turn the lights off?” and “Typically, on weekdays, how long does it take you (in minutes) to fall asleep?” We then used these answers to calculate the sleep values reported here.

(1) Total Sleep Time (TST) was calculated based on the typical hours reported for sleeping time, awakening time, wake after sleep onset (WASO) duration, and sleep onset latency. Representative questions included: “Typically, at what time do you turn off the light to sleep?”, “Typically, how long does it take you to fall asleep?”, “Do you sometimes wake up during the night and find it difficult to fall back asleep? If YES, in general, how long do you stay awake per night?”, and “Typically, at what time do you wake up in the morning?” In contrast to surveys that try to combine time in bed (TIB) with reading or other activities in bed, our goal was to assess an actual TST comprising: sleeping time — sleep latency —
WASO – awakening time. These questions were asked separately for working days (weekdays) and leisure days that may be assimilated by most of the subjects (but not all, depending on the occupation by weekends), and an average TST was calculated as: \((5 \times \text{TST}_W \text{ (week)} + 2 \times \text{TST}_W \text{ (weekend)}) \div 7\).

(2). Total Nap Time (TNT) per day was obtained by multiplying the number of naps per average nap length, and dividing by five on weekdays, or by two on weekends. Individuals answered the following questions: “Typically, how many times do you nap per week, during weekdays/on weekends?”, and “Typically, how long do your naps last, during weekdays/on weekends?”. These questions were asked separately for work days (weekdays) and weekends, and an average TNT was calculated as: \((5 \times \text{TNT}_W \text{ (week)} + 2 \times \text{TNT}_W \text{ (weekend)}) \div 7\).

(3) Average Total Sleep Time per 24 h (TST/24) during weekdays and weekends was obtained by adding the TST and TNT values during weekdays and weekends. Average TST/24 was calculated as: \((5 \times \text{TST}_W \text{ (week)} + 2 \times \text{TST}_W \text{ (weekend)}) \div 7\).

(4). Self-reported ideal TST was obtained as the answer to the question: “Typically, how many hours of sleep do you need to be in good shape the following day?”

(5). Subjects were classified as having chronic insomnia according to the International Classification of Sleep Disorders, third edition (ICSD-3) [35]. For this, we asked the following YES-NO questions: Typically, do you find it difficult to fall asleep? Do you often wake up at night and find it difficult to fall back asleep? Do you typically wake up too early in the morning and find it impossible to fall back asleep? If yes, is it: (a) less than three nights per week; or (b) three nights or more per week? And if yes, do you have these problems for more than three months at a time? Do these sleep difficulties have a negative impact on your daytime activities, work, schoolwork, relationships with others, leisure activities, learning, or mood, or make you more irritable?

2.3. Sleep paradigms

We retained other definitions that we defined in several previous surveys, in order to reflect the categories and adaptation of TST over a 24-h period [8,36–38]:

- The definition of short sleepers and long sleepers is based on TST_W. Indeed, in many surveys (including our first ones), short and long sleepers referred to TST on weekdays and weekends. We find it more realistic to take TST_W as a reference.
  - Short sleepers: those with TST_W < 6 h
  - Long sleepers: those with TST_W > 8 h
- Sleep debt is defined as ideal TST – TST_W > 60 min, while the term severe sleep debt is used for a difference > 90 min [20].
- Sleep restriction is defined as TST_WE – TST_W > 60 min, with a moderate sleep restriction in the range of 61–120 min, and severe sleep restriction > 120 min.

In addition to these paradigms, we also referred to TST/24 in order take account of the role of napping in sleep debt and sleep restriction.

- "Non-balanced sleep debt per 24 h" is defined as Self-reported ideal TST – TST/24 > 60 min, whereas "Non-balanced severe sleep debt per 24 h" is used if this difference is > 90 min.

- Sleep restriction per 24 h is defined as TST_WE/24 – TST_W/24 > 60 min, with a moderate sleep restriction per 24 h in the range of 61–120 min, and severe sleep restriction per 24 h > 120 min.

2.4. Statistical analyses

The statistics presented (percentages and odds ratios) correspond to weighted and adjusted results based on the National Institute of Statistics and Economic Studies (INSEE) survey data on sex and age groups, geographical area, family size, urban area size, and education level, in the metropolitan French-speaking population [39]. We used Pearson’s chi-squared tests (with Rao-Scott second-order corrections) in a bi-variate analysis. Odds ratios (OR) are presented with their 95% confidence intervals (± x). The quantitative values were compared by ANOVA within the age groups.

Multivariate analyses using repeated measures ANOVA allowed testing the associations between self-reported short sleep and chronic insomnia, as well as: (i) sleep debt and sleep debt per 24 h; (ii) balanced and non-balanced sleep debt per 24 h; and (iii) both sleep restriction and sleep restriction per 24 h. The data displayed a normal distribution (Shapiro–Wilk normality test). Mean values were computed and the group-level variance was expressed using the standard error of the mean (SEM). A probability level of P < 0.05 was considered statistically significant.

3. Results

3.1. TST

The self-reported average TST for the entire group of responders was 6h45 (± 2 min), showing similar values for women (6h44 ± 4 min) and men (6h46 ± 3 min), with no significant difference between the sexes (NS). The TST_W value, 7h12 (± 0.3 min), was significantly longer than the TST_W value, 6h34 (± 0.2 min; p < 0.001) (Table 1).

The average TST/24 was composed of an average 6h45 (± 2 min) at night plus an average 8.3 (± 0.5) minutes of napping. On average, our subjects self-reported a sleep latency of 24.6 (± 0.6) minutes and a WASO of 34 (± 1.1) minutes, although we observed a value of 69.6 (± 1.6) minutes among the 48.9% of subjects who reported WASO (Table 1).

Based on self-reported nocturnal TST, 35.9% (± 4%) of the subjects were short sleepers, with no significant difference between the sexes (NS), and 35.1% (± 1%) had sleep debt, while 24.2% (± 0.9%) showed severe sleep debt, based on TST at night. According to TST/24, 27.7% (± 1%) of subjects reported a non-balanced sleep debt and 18.8% (± 0.8%) a severe non-balanced sleep debt. Notably, women reported significantly more non-balanced sleep debt (23.1 ± 1.3%) than men (14.3 ± 1.1%); p < 0.001. However, there was no significant difference between the sexes regarding sleep restriction: 15.7% (± 0.9%) of men and 16.2% (± 1.1%) of women reported a moderate sleep restriction (NS), whereas 12.5% (± 1%) of men and 10.7% (± 0.9%) of women had severe sleep restriction (NS) (Table 1).

Self-reported TST/24 did not vary significantly with individual socio-demographic characteristics, except for occupation. For example, working individuals had a shorter average TST (6h48 ± 4 min) than students (7h19 ± 5 min); p < 0.001. Subjects in a difficult financial position slept on average 20 min less than those who did not declare any financial problems. However, the rate of short sleepers appeared significantly higher in those who work but also in those with lower diploma levels, those who are single or live in large families, those in lower socio-occupational levels, and
Self-reported total sleep time, sleep loss, napping, short sleep, sleep debt, sleep restriction and insomnia among the total group and among sexes.

### SLEEP VALUES

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>CI 95%</th>
<th>Men</th>
<th>CI 95%</th>
<th>Women</th>
<th>CI 95%</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>TST ideal (hours-minutes)</td>
<td>7h14</td>
<td>7h12–7h16</td>
<td>7h01</td>
<td>6h58–7h03</td>
<td>7h27</td>
<td>7h24–7h29</td>
<td>**</td>
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<tr>
<td>TST at night</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weekdays–workdays (hours)</td>
<td>6h34</td>
<td>6h32–6h36</td>
<td>6h34</td>
<td>6h30–6h37</td>
<td>6h34</td>
<td>6h31–6h38</td>
<td>NS</td>
</tr>
<tr>
<td>Weekends/leisure days</td>
<td>7h12</td>
<td>7h10–7h15</td>
<td>7h16</td>
<td>7h12–7h20</td>
<td>7h09</td>
<td>7h06–7h13</td>
<td>NS</td>
</tr>
<tr>
<td>Averaged TST at night</td>
<td>6h45</td>
<td>6h43–6h47</td>
<td>6h46</td>
<td>6h42–6h49</td>
<td>6h44</td>
<td>6h41–6h48</td>
<td>NS</td>
</tr>
<tr>
<td>Sleep loss at night</td>
<td>34.2</td>
<td>33.0–35.3</td>
<td>26.4</td>
<td>24.8–27.9</td>
<td>41.5</td>
<td>39.9–41.3</td>
<td>***</td>
</tr>
<tr>
<td>WASO (minutes)</td>
<td>69.6</td>
<td>68.0–71.3</td>
<td>66.3</td>
<td>63.5–69.1</td>
<td>71.8</td>
<td>69.8–73.8</td>
<td>NS</td>
</tr>
<tr>
<td>SOL (minutes)</td>
<td>24.6</td>
<td>23.9–25.2</td>
<td>21.6</td>
<td>20.7–22.4</td>
<td>27.4</td>
<td>26.4–28.3</td>
<td>**</td>
</tr>
<tr>
<td>Napping</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% of subjects with at least one nap per week (%)</td>
<td>27.4</td>
<td>26.4–28.3</td>
<td>30.4</td>
<td>28.9–31.8</td>
<td>24.5</td>
<td>23.2–25.9</td>
<td>***</td>
</tr>
<tr>
<td>Average length of one nap (in nappers only) (minutes)</td>
<td>49.8</td>
<td>48.1–51.5</td>
<td>47.8</td>
<td>45.5–50.2</td>
<td>52.1</td>
<td>49.6–54.6</td>
<td>NS</td>
</tr>
<tr>
<td>Averaged napping duration / on weekdays-workdays (min.)</td>
<td>8.3</td>
<td>7.8–8.8</td>
<td>9.4</td>
<td>8.6–10.1</td>
<td>7.3</td>
<td>6.7–8.0</td>
<td>NS</td>
</tr>
<tr>
<td>Subjects with at least one nap per weekend/leisure day (%)</td>
<td>32.2</td>
<td>31.1–33.2</td>
<td>35.6</td>
<td>34.1–37.1</td>
<td>29</td>
<td>27.6–30.3</td>
<td>**</td>
</tr>
<tr>
<td>Average length of one nap (in nappers only) (minutes)</td>
<td>59</td>
<td>57.2–60.8</td>
<td>57.7</td>
<td>55.1–60.3</td>
<td>60.6</td>
<td>58.2–63.0</td>
<td>NS</td>
</tr>
<tr>
<td>Averaged napping duration / on weekends-leisure days (minutes)</td>
<td>13.7</td>
<td>13.0–14.3</td>
<td>14.8</td>
<td>13.8–15.8</td>
<td>12.6</td>
<td>11.7–13.5</td>
<td>NS</td>
</tr>
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</table>

### SLEEP PARADIGMS

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>NS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short – sleepers/Long-sleepers</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>Short sleeper (TST at night weekdays/working days &lt;= 6h)</td>
<td>35.9</td>
<td>34.9–36.9</td>
</tr>
<tr>
<td>Reference group</td>
<td>48.2</td>
<td>47.2–49.3</td>
</tr>
<tr>
<td>Long sleeper (TST at night weekdays/working days &gt; 8h)</td>
<td>15.8</td>
<td>15.0–16.7</td>
</tr>
<tr>
<td>Sleep debt</td>
<td>**</td>
<td></td>
</tr>
<tr>
<td>% with sleep debt (&gt;60 min)</td>
<td>35.1</td>
<td>34.1–36.2</td>
</tr>
<tr>
<td>% with severe sleep debt (&gt;90 min)</td>
<td>24.2</td>
<td>23.3–25.1</td>
</tr>
<tr>
<td>Sleep debt per 24 hours</td>
<td>**</td>
<td></td>
</tr>
<tr>
<td>% with non-balanced 24 hours sleep debt (&gt;60 min)</td>
<td>27.7</td>
<td>26.8–28.7</td>
</tr>
<tr>
<td>% with non-balanced 24 hours severe sleep debt (&gt;90 min)</td>
<td>18.8</td>
<td>18.0–19.7</td>
</tr>
<tr>
<td>Sleep restriction</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>No restriction (1 hour or less)</td>
<td>72.5</td>
<td>71.5–73.4</td>
</tr>
<tr>
<td>Moderate restriction (1–2 hours)</td>
<td>15.9</td>
<td>15.2–16.7</td>
</tr>
<tr>
<td>Severe restriction (more than 2 hours)</td>
<td>11.6</td>
<td>10.9–12.3</td>
</tr>
<tr>
<td>Sleep restriction on 24 hours</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>No restriction (1 hour or less)</td>
<td>68.2</td>
<td>67.1–69.2</td>
</tr>
<tr>
<td>Moderate restriction (1–2 hours)</td>
<td>17.4</td>
<td>16.6–18.3</td>
</tr>
<tr>
<td>Severe restriction (more than 2 hours)</td>
<td>14.4</td>
<td>13.6–15.2</td>
</tr>
<tr>
<td>Chronic insomnia</td>
<td>**</td>
<td></td>
</tr>
<tr>
<td>DSM V (chronic insomnia, at least 3 months)</td>
<td>13.1</td>
<td>12.4–13.9</td>
</tr>
</tbody>
</table>

Legend and abbreviations: Sleep values: TST = total sleep time, CI = confidence interval, WASO = wake after sleep onset, SOL = sleep onset latency, % = percentage, min. = minutes, h = hours. For short sleep, long sleep, sleep debt, sleep debt/24h, sleep restriction, sleep restriction/24, ICSD chronic insomnia, see definitions in the Methods section. Sleep paradigms. NS, **, ***: significant differences: non–significant, and significance levels of 1% and 0.1%.

3.1. Schedules of night sleep on workdays (weekdays) and leisure days (weekends)

The average “lights off” time on weekdays was 23:15 (± 7 min), and the awakening time was 6:48 (± 6 min); on weekends, “lights off” was midnight (00:00 ± 6 min) and awakening time was 8:10 (± 6 min).

3.2. TST/24 among age groups

The self-reported average TST/24 decreased progressively from 7h24 (± 4 min) in the 18-24-year-old group, to 6h35 (± 3 min) among 45-54-year-olds (p < 0.001), and increased to 6h48 (± 4 min) in 55-64-year-olds and 6h58 (± 4 min) among the elderly (65–75 years old; p = 0.01 vs. the 45-54-year-old group). We observed the same trend for weekday TST/24. However, TST/24 on weekends constantly decreased from 8h19 (± 5 min) in 18–24-year-olds, to 6h58 (± 4 min) in 65–75-year-olds; p = 0.01 vs. the 45-54-year-old group. In this last age group (65–75), TST/24 on weekdays and weekdays was identical (Fig. 1). TST/24 was constantly shorter than the self-reported ideal TST, whatever the age group, by an average of 20–25 min.

3.3. Napping time among age groups (Table 3)

In total, 27.4% (± 0.9%) of subjects announced napping at least once per week on weekdays for an average of 49.8 (± 1.7) minutes, while 32.2% (± 0.9%) napped once per weekend, for an average of 59 (± 1.8) minutes. The average napping length during weekdays (across the entire group, including people who never nap) was 8.3 (± 0.5) minutes, whereas it was 13.7 (± 0.6) minutes on weekends (NS). Among nappers, the average self-reported nap length on weekdays decreased progressively with increasing age, from 63 (± 1.9) minutes in the 18-24-year-old group, to 41 (± 0.8) minutes in the 65-75-year-old group (p < 0.001). On weekends, nap length similarly decreased from 82 (± 3.1) minutes to 45 (± 1.5) minutes in these relative age groups (p < 0.001). Conversely, the rates of nappers on weekdays (20–30%) was relatively similar from 18 to 64 years old.
years old, and significantly higher (42 ± 0.9%) in 65–75-year-olds vs. other age groups; p < 0.001. Regarding napping on weekends, 20.1% (± 0.4%) of 18–24 year-olds were concerned as compared to 36.1% (± 0.4%) of 45–54 year-olds; p < 0.001 within age groups.

### 3.4. Chronic insomnia

According to the ICSD-3 definition of self-reported items [35], 13.1% (± 0.8%) of the subjects were classified as having chronic insomnia: 16.9% (± 1.1%) of women and 9.1% (± 0.9%) of men; p < 0.001. Chronic insomnia was even significantly more self-reported in the youngest women (14.4 ± 0.8% of 18–24-year-olds) than in the youngest men (7 ± 0.6% of 18–24-year-olds) (p < 0.001). Whatever the age group, women reported about twice more insomnia than men (Fig. 2).

### 3.5. Sleep debt among age groups

Sleep debt was also significantly more prevalent in women than in men (p < 0.001). Regarding age groups, we found a higher rate of sleep debt in 18–54-year-olds than in older subjects between 55 and 75 years old; p < 0.001. The average sleep debt per 24 h concerned a smaller rate of adults, due to napping and weekend catch-up sleep, which partially balanced the accumulated sleep debt of the week and came close to the self-reported ideal sleep time (Fig. 3).

Regarding the sociological characteristics of subjects with severe sleep debt, subjects were significantly more often women, younger, with lower income, a sedentary lifestyle, and living in a couple with kids (all significant at p < 0.001).

### 3.6. Sleep restriction among age groups (Fig. 4)

Both men and women from the 18–25-year-old group were significantly more affected by sleep restriction as well as sleep restriction in a 24-h period (between 25 and 30%). Between 25 and 54 years of age, severe sleep restriction per 24 h was slightly more frequent in men (18 ± 1.2%) than in women (15 ± 1%); p = 0.01. Above 65 years of age, around 1% of subjects had sleep restriction,
signifying that most subjects slept the same amount on weekdays and weekends.

3.7. Chronic insomnia, short sleep, sleep debt, and sleep restriction

Using multivariate analysis, we found a significant association between self-reported short sleep and insomnia: 22.3% of short sleepers complained of insomnia vs. 8.5% in the reference group (non-short and non-long sleepers) (p < 0.001); reciprocally, 61% of subjects with insomnia were short sleepers vs. 13.1% of the total group (p < 0.001). There was also a significant association between sleep debt and insomnia (p < 0.001; Table 4), but no significant association between sleep restriction and insomnia (NS). Moreover, 76% of subjects with severe sleep debt, 81% with non-balanced severe sleep debt, 60% with severe sleep restriction, and 61% with chronic insomnia were significantly more often short sleepers than the total group (p < 0.001; Table 4).

3.8. Nappers or catch-up sleepers: how they compensate for sleep debt?

Among the 35.1% (± 1.0%) of subjects with sleep debt (> 1 h), 16.8% (± 1.1%) balanced (compensated) their sleep debt by catching up on weekends, including 16.3% (± 1.0%) of men and 17.4% (± 1.2%) of women. Furthermore, 7.1% (± 0.8%) of these subjects balanced it by napping, with 8.3% (± 0.6%) of men and 6% (± 0.3%) of women. The remaining 76.4% (± 5.6%) did not balance their sleep debt.

Out of the 24.2% (± 0.9%) of subjects with severe sleep debt (> 90 min), 18.2% (± 1.6%) balanced their sleep debt by catching up on sleep on weekends (14.9% of men and 21.5% of women), and 7.4% (± 1.2%) of these subjects balanced it by napping (7.8 ± 0.5% of men and 6.6 ± 0.4% of women). The remaining 75.8% (± 5.4%) did not balance their severe sleep debt.

3.9. Shift workers

Inside the total group, 602 subjects (4.8%) reported they were shift workers. Their self-reported average TST was 6h11 (± 4.9 min) significantly shorter than the total group of responders (6h45 ± 2 min; p < 0.001). The TSTWE value was 6h39 (± 7.4 min), and was non-significantly different from the TST value of the group (6h34 ± 0.2 min; p = 0.056). The self-reported average TST/24 was 6h58 (95% CIs = ± 4.8 min), and was not significantly different from the entire group of responders (6h42 ± 2 min; p = 0.122). The TST/24WE value was 7h18 (± 7.4 min), and was non-significantly different from the TSTW value of the group (7h26 ± 3 min; p = 0.07). Based on self-reported nocturnal TST, 62.8% (± 4.0%) of shift workers had sleep debt (vs. 35.1 ± 1.3% of the...
4. Discussion

One major challenge of our survey was collecting the TST data from a large representative sample of the general population, not only on weekdays but also on weekends, and not only at night but also during a 24-h period, while taking account of napping. In discussing the role of sleeping too little (short sleep) as a health factor in comorbidities and mortality, most authors have only considered sleep at night, and occasionally have only required a single question such as “How much do you think you sleep at night?” to assess TST [9–11,14,15]. In our study, we demonstrate that it is clearly possible to interview a large number of adults not only at night, but also regarding how they sleep during a 24-h period, including sleep latency and WASO.

It is generally accepted that the gold standard for assessing sleep is polysomnography (PSG), which allows accurately calculating TST.
as well as the percentages of rapid eye movement (REM) and non-REM sleep. However, it is clearly difficult to study a large group of subjects by PSG, and in epidemiology the use of sleep logs is more natural, and they appear to be more appropriate for capturing the sleep habits of all age groups. Thus, sleep logs, like the self-reported one we have used, make it possible to interview thousands of people about their sleep habits. For example, it may be difficult for the elderly to assess the difference between weekdays and weekends. Our sleep log telephone interview allows the elderly to integrate within their answers such altruistic factors as family and

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**Table 4**

Multivariate association between ICSD-3 subjects with chronic insomnia, short sleep, sleep debt and sleep restriction.

<table>
<thead>
<tr>
<th></th>
<th>% with chronic insomnia</th>
<th>% of short sleepers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Short-sleep/Long-sleep</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Short sleep (TSTW ≤ 6 h)</td>
<td>22.3</td>
<td></td>
</tr>
<tr>
<td>Reference group</td>
<td>8.5</td>
<td></td>
</tr>
<tr>
<td>Long sleep (TSTW &gt; 8 h)</td>
<td>6.4</td>
<td></td>
</tr>
<tr>
<td><strong>Sleep debt</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No debt</td>
<td>7.3</td>
<td>19.3</td>
</tr>
<tr>
<td>Sleep debt (&gt; 60 min)</td>
<td>23.6</td>
<td>66.3</td>
</tr>
<tr>
<td>Severe sleep debt (&gt; 90 min)</td>
<td>27.6</td>
<td>76.2</td>
</tr>
<tr>
<td><strong>Sleep debt per 24 h</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No debt</td>
<td>7.9</td>
<td>22.4</td>
</tr>
<tr>
<td>Non balanced sleep debt per 24 h (&gt; 60 min)</td>
<td>26.3</td>
<td>70.7</td>
</tr>
<tr>
<td>Non balanced severe sleep debt per 24 h (&gt; 90 min)</td>
<td>30.4</td>
<td>80.6</td>
</tr>
<tr>
<td><strong>Sleep restriction</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No restriction (&lt; 60 min)</td>
<td>13.4</td>
<td>31.2</td>
</tr>
<tr>
<td>Sleep restriction (1 h–2 h)</td>
<td>11.4</td>
<td>40.2</td>
</tr>
<tr>
<td>Severe sleep restriction (&gt; 2 h)</td>
<td>13.8</td>
<td>59.6</td>
</tr>
<tr>
<td><strong>Sleep restriction per 24 h</strong></td>
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<td></td>
</tr>
<tr>
<td>No restriction (&lt; 60 min)</td>
<td>13.6</td>
<td>31.1</td>
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<tr>
<td>Sleep restriction (1 h–2 h)</td>
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<tr>
<td>Severe sleep restriction (&gt; 2 h)</td>
<td>13.6</td>
<td>55.8</td>
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<tr>
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<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>—</td>
<td>32.2</td>
</tr>
<tr>
<td>Yes</td>
<td>—</td>
<td>61.0</td>
</tr>
</tbody>
</table>

**Legend:** 22.3% of short sleepers had insomnia vs. 8.5% in the reference group and 6.4% of long sleepers. TST = total sleep time, TSTW = total sleep time on weekdays; % = percentage; min = minutes; h = hours; ns = non-significant and *** = significant differences on multivariate analysis, at significance levels of 5% and 0.1%.

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**Fig. 4.** Percentage of subjects with severe sleep restriction (TST-WE – TST-W) at night during a 24-h period, among sex and age groups.

**Legend and abbreviations:** TST = total sleep time, TST/WE = total sleep time on weekends, TST/W = total sleep time on weekdays; % = percentage, yo = years old, NS (non-statistically significant). Both sleep restriction and sleep restriction per 24 h concerned more significantly the 18-25-year-old group for both men and women (between 25% and 30%) compared to the other groups (p < 0.001). Between 25 and 54 years of age, severe sleep restriction per 24 h was slightly more frequent in men (18%) than in women (15%) (NS).

Above 65 years of age, around 1% of subjects had sleep restriction, signifying that most subjects slept the same amount on weekdays and weekends.
sociocultural habits, and environmental factors like noise level or weekend settings. From a clinical point of view, it is also possible to ask patients about their sleep schedules, by interviewing them using the same items and getting the same values for TST, napping, etc. [40]. From an epidemiological point of view, we have already used these sleep logs in several previous studies with blind people, who responded to questions with the help of microphones that recorded their voice, or using braille questionnaires [41,42]. Therefore, our methodology may help such older subjects in clearly differentiating weekday sleep from weekend sleep.

Overall, this survey strongly confirms the high prevalence of sleep debt in the adult French population. Nearly one-fourth (24.2%) of adults (28.9% of women and 19.2% of men) had severe sleep debt (signified by a difference of greater than 90 min between TSTW and self-reported ideal TST), whereas 18.2% of the group had a non-balanced sleep debt without any way to get more sleep during a 24-h period. However, since the actual sleep durations were not different for men versus women, it seems that the difference in sleep debt could be driven by a higher self-reported ideal sleep time in women versus men (7h27 vs. 7h01). Moreover, 14.4% of subjects had severe sleep restriction during weekdays, with more than two hours of TST difference on weekends. This is a crucial issue at the population level, potentially concerning millions of people, and regarding more men than women (Fig. 1). Nevertheless, it is not clear how we can determine the evolution of the amount of sleep debt in different countries. Indeed, our survey calculated the rates of sleep debt and sleep restriction based on a very concise 24-h sleep log, and not only during a single night. We also acknowledge that our definition of sleep debt referred to a difference with the subjective “self-reported ideal TST”. Subjects likely based their answer about “Self-reported ideal TST” on their beliefs and experiences of their own sleep, but not on an objective measurement of sleep by PSG. This explains why it is not easy to confirm whether or not, sleep deficit has increased in the past decade in other countries [20,21].

These impressively high sleep debt and restriction rates are indeed associated with a high proportion of short sleepers in our sample: we observed a rate of 35.9%, double what we observed in 2010 (17.6%) using the same sleep log at night [43]. This means that more than one-third of the adult population is potentially exposed to this short-sleep risk factor along with associated obesity, type 2 diabetes, cardiovascular diseases, and motor vehicle accidents [5–13]. Several surveys have shown that sleep schedules and transportation time (between home and work) are among the most significant factors contributing to short sleep [20,21,44,45]. However, sleep schedules are indeed responsible in shortening sleep, probably due to the overuse of screens at bedtime. Although we did not check screen use in this survey, sleep schedules were indeed slightly late (with an average “lights off” at 23:15, and awakening at 6:48). In addition, we also found a low rate of long sleepers (15.8%), as compared to the 28.9% rate observed in the BS 2010 survey [8,43].

One limitation of our survey is that the definition of short sleep we used (TST_W ≤ 6 h) may be considered relatively strict. The current recommendation made by the international Sleep Research Society and the American Academy of Sleep Medicine (AASM) is that “adults should sleep seven or more hours per night on a regular basis to promote optimal health. Sleeping less than 7 h per night on a regular basis is associated with adverse health outcomes” [46].

One positive issue in our survey was napping habits. Indeed, researchers consider napping to be the most adaptive and efficient means to cope with sleep debt [24]. In our survey, we observed that more than one-fourth of adults (27.4%) napped at least once per week, with an average duration of 50 min. Moreover, about one-third (32.2%) napped on weekends for an average of 59 min. However, if we consider average napping length in the entire group, including individuals who reported zero napping, (8.3 min), it is easy to understand that nap duration at a population level was highly influenced by the participants that did not nap. Napping is not so easy, and the remaining 72.6% of the subjects did not report any napping at all (0 minutes). The youngest subjects had the longest naps on weekends, with an average of 82 min per nap. This ability to nap in order to compensate for sleep debt is a major goal of health education. Indeed, we believe that denouncing the deleterious impact of sleep loss is not sufficient, and that we must propose easy-to-apply countermeasures to the greater public, youth and media. Napping is both an involuntary and voluntary behavior, whose involuntary side reflects the natural adaptive ability to cope with sleep debt. Napping as a voluntary strategy can be used to counter sleep debt in a highly intense period of work or sport performance, and it is particularly recommended for night and shift workers with poor sleep, in order to avoid sleep-related accidents [24].

Adults do not commonly nap at work, as it is difficult to organize and implement nap settings in the workplace. Our survey reflects how every adult age group adheres to naps, and shows that it is probably easy to recover the lost sleep, depending on the age group and several socio-demographic characteristics. However, our analysis also shows that only 7.1% of those with sleep debt and 7.4% with severe sleep debt balance their sleep debt by napping on weekdays, which demonstrates that in real life only a limited number of people use napping as a countermeasure.

Another aspect of sleep debt in adults is that they balance this debt by catching up on sleep on weekends, particularly in the 35-54-year-old group. Catching up on sleep on weekends appears to limit the comorbid risks associated with sleep debt [32]. Thus, it seems possible to recommend weekend catch-up sleep to younger sleep-deprived groups that show the highest sleep restriction. Nevertheless, some recent laboratory data have rejected the effect of “ad libitum” weekend catch-up sleep on metabolic risk. Specifically, the authors of this particular research suggested that weekend recovery is not an effective strategy to prevent metabolic dysregulation associated with recurrent insufficient sleep [26].

We also observed, based on self-reported items, relatively low rates of people with sleep debt (16.8%) and severe sleep debt (18.2%) that use catch-up sleep to balance their sleep debt. We believe that conversely to napping, catch-up sleep on weekends should not be recommended to people with sleep debt. Nevertheless, it could be proposed as a short-term solution to people exposed to acute sleep debt due to professional or personal events. However, on the long-term, we believe that catch-up sleep during the weekend may expose people to a loss of socialization as well as “social jet-lag”, which has been defined as a misalignment of biological and social time [47]. People that use catch-up sleep on weekends could possibly delay their sleep schedules and lose their social reference points with their families and friends.

Another positive finding in our survey was the relatively low prevalence of insomnia in the adult population (13.9%), which was significantly lower in males (ie, less than 10%). By comparison, the adult prevalence of insomnia, based on ICSD-3 criteria, is between 15 and 20% in many countries [48]. The original survey in 2000 found a 19% prevalence in France [26]. The last BS 2010 survey identified 16.1% of adults with chronic insomnia [49]. The 45–54 and above 65-year-old groups showed the most significant improvement. Observing the association between short sleep and insomnia (Table 4), it can be hypothesized that sleep restriction and our deficit in the total group had an impact on the prevalence of insomnia. As we know, one basis for treating insomnia by behavioral cognitive therapy (BTC) is to reduce total time in bed (TIB). It is
possible that French adults exposed to sleep debt have naturally decreased their exposure to insomnia. However, this hypothesis is up for discussion, since sleep restriction was not individually organized based on sleep logs like in the BCT practical rules. Moreover, one limitation of the survey is that we did not inquire about other sleep disorders, like obstructive sleep apnea (OSA), which can impair both sleep quality and daytime sleepiness.

Finally, our observation of self-reported TST in France gives us a more natural and rich description of the sleep behaviors of adults at night as well as during the day, and on workdays as well as on weekends. As TST is a crucial health factor associated with chronic diseases, we believe that working on countermeasures like napping or sleep extension may have a dramatic impact on disease prevention, similar to the effects of nutrition and exercise, whose links with sleep have been strongly demonstrated [30].

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**CRediT authorship contribution statement**

**Damien Leger:** Conceptualization, Formal analysis, Writing - original draft. **Jean-Baptiste Richard:** Conceptualization, Formal analysis, Writing - original draft. **Olivier Collin:** Formal analysis. **Fabien Sauvet:** Formal analysis. **Brice Faraut:** Formal analysis.

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**Appendix A. Supplementary data**

Supplementary data to this article can be found online at https://doi.org/10.1016/j.sleep.2020.05.030.

**Conflict of interest**

Dr. Léger declares that in the past five years he has been employed as an investigator or a consultant by Actellion-Ildora, the Agence Spatiale Européenne, Bioprojet, iSommeil, ESIi, Janssen, Jazz, Vanda, Merck, Philips, Rythm, Sanofi, Vitalaire, and Resmed.

The other authors had no conflicts of interest.

The ICMJE Uniform Disclosure Form for Potential Conflicts of Interest associated with this article can be viewed by clicking on the following link: https://doi.org/10.1016/j.sleep.2020.05.030.

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