Chronic sleep reduction in adolescents
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Citation for published version (APA):

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“A good laugh and a long sleep are the best cures in the doctor's book.”

-Irish Proverb-
Chapter 5

Why sleep matters: Individual differences in sleep need and vulnerability to sleep loss

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Under review (revision submitted)
Abstract

This study aims to investigate individual differences in sleep need and examines differences in vulnerability to sleep loss. The sample consisted of 932 adolescents (mean age: 14.68 years). Extreme groups (lowest and highest quartiles) of adolescents with low and high chronic sleep reduction (measured by the Chronic Sleep Reduction Questionnaire) and short and long sleep durations were identified. Symptoms of sleep reduction did not appear to coincide with the amount of sleep duration, suggesting individual differences in sleep need. Furthermore, differences in daytime functioning between adolescents that were grouped according to their sleep give evidence of individual differences in vulnerability to sleep loss.
5.1. Introduction

Many adolescents suffer from sleep problems, which can negatively affect their daytime functioning (Curcio, Ferrara, & De Gennaro, 2006; Dewald, Meijer, Oort, Kerkhof, & Bögels, 2010; Fallone, Owens, & Daene, 2002; Mitru, Millrood, & Mateika, 2002; Moore et al., 2009; Wolfson & Carskadon, 2003). Insufficient sleep is a common phenomenon in this age group and its main cause can be found in an interaction of extrinsic (e.g., social pressure, academic workload) and intrinsic factors (e.g., circadian and/or homeostatic changes) that occur during puberty (Wolfson & Carskadon, 2003). While these factors cause shorter sleep durations, adolescents’ sleep need does not decrease, often resulting in chronically reduced sleep.

Which amount of insufficient sleep actually results in chronic sleep reduction and whether all adolescents are equally susceptible to chronic sleep reduction and to its consequences are important research questions. It has been pointed out that no exact amount of ‘optimal’ sleep exists, highlighting individual differences in sleep need (Ferrara & De Gennaro, 2001). Based on experimental sleep deprivation studies in adults, van Dongen, Rogers, and Dinges (2003) concluded that sleep duration should be interpreted in reference to one’s individual sleep need (i.e. amount of sleep an individual needs to be fully awake, and not sleepy, during the day). Furthermore, neurobehavioral performance impairment due to sleep deprivation could be ascribed to individual differences in vulnerability to sleep loss (van Dongen, Baynard, Maislin, & Dinges, 2004). Rajaraman, Gribok, Wesensten, Balkin, and Reifman (2008) demonstrated that performance of sleep-deprived individuals can be predicted by three distinct performance phenotypes, namely relatively vulnerable to sleep loss, relatively average sensitivity to sleep loss, and relatively resilient to sleep loss. As both individual sleep need and vulnerability to sleep loss may obscure associations between sleep and daytime functioning, it is important to include these phenomena when investigating such relationships.

Assessment of sleep need and vulnerability to sleep loss is generally done within small experimental sleep deprivation or sleep restriction studies with adults. In these studies sleep duration is (gradually) restricted or totally deprived, with the consequence that participants sleep less than their individual sleep need. To date, impairments in daytime functioning that result from vulnerability to (chronic) sleep loss have not been examined. The absence of such studies may be caused by the fact that the effects of sleep duration on daytime functioning are difficult to determine as sleep duration does not account for individual sleep need. To overcome this problem, Meijer (2008) developed the Chronic Sleep Reduction Questionnaire (CSRQ) assessing chronic sleep reduction by measuring symptoms of insufficient and/or poor sleep rather than (shortened) sleep duration directly.
The questionnaire is based on the assumption that these symptoms need some time to become present and therefore occur only in individuals that experience insufficient and/or poor sleep over a long time period. Consequently, the CSRQ also addresses the aspect of chronicity, which is often overlooked by studies that use measures of sleep duration. The CSRQ is developed for adolescents, a group that seems particularly susceptible to insufficient sleep (Gibson et al., 2006; Roberts, Roberts, & Xing, 2010).

As the assumption of individual sleep need is an important aspect of the CSRQ, the present study examines whether low and high chronic sleep reduction (using the CSRQ) corresponds with long and short sleep duration. This approach gives more insight into the assumption that sleep should be interpreted in reference to one’s sleep need.

Furthermore, to test the idea of individual differences in vulnerability to sleep loss, this study examines the proportion of cases with poor outcomes of extreme groups (based on upper and lower quartiles) and studies whether daytime functioning can discriminate between individuals that are grouped according to their sleep. In this way, we compare differences in daytime functioning of adolescents that experience the same amount of sleep or chronic sleep reduction (measured by the CSRQ). Consequently, we gain more insight into the question whether looking at symptoms of insufficient sleep instead of sleep duration might improve the predictability of vulnerability to sleep loss. In addition, we study whether adolescents with chronic sleep reduction or short sleep durations have a higher risk to score clinically on daytime functioning variables than adolescents with low chronic sleep reduction or long sleep durations.

Many studies demonstrate a significant relationship between sleep and daytime functioning, such as depressive symptoms, attention, and sleepiness (e.g., Gregory & Sadeh, 2012; Mitru et al., 2002; Moore et al., 2009). Additional key components of adolescents’ daytime functioning are school performance and school functioning, representing aspects of cognitive performance, self-perception, and social interactions. As different facets of school functioning may contribute to school success, the present study includes three concepts of school functioning that have been repeatedly associated with school performance: (1) achievement motivation (Guay, Ratelle, & Chanal, 2008; Guay, Ratelle, Roy, & Litalien, 2010), referring to the processes that energize and orient competence strivings (Elliot & Dweck, 2005), (2) teacher-child relationship (Birch & Ladd, 1997; Gregory & Ripski, 2008; Valiente, Lemery-Chalfant, Swanson, & Reiser, 2008), reflecting the interactions between student and teacher, and (3) academic self-concept (Ferla, Valcke, & Yonghong, 2009; Marsh & Yeung, 1997), which refers to an evaluative self-perception that is formed through the student's experience and interpretation of the school environment (Marsh & Craven, 1997). Although it has repeatedly been shown that sleep is significantly related to school
performance, this relationship often appears to be rather small (Dewald et al., 2010). One explanation for the small effect sizes can be found in evidence demonstrating that the relationship between sleep and school performance is mediated by school functioning (Meijer, 2008). To give a full picture of daytime functioning in adolescents and its relationship with sleep, we include depression, attention, sleepiness, school performance, achievement motivation, teacher-child relationship, and academic self-concept in this study. The present study aims to investigate individual differences in sleep need and examines differences in vulnerability to sleep loss.

5.2. Method
5.2.1. Sample
Participants were recruited via flyers and information on school websites. 954 participants completed the questionnaires. Twenty-two adolescents were excluded because they were too old (≥ 20 years) or because either their CSRQ scores or sleep duration were considered as outliers (α = .001). The final sample consisted of 932 adolescents (mean age: 14.68 years (SD = 1.66 years); 41% boys). In 80.5% both parents were employed, in 18.6% one parent was employed and in 1% neither mother nor father was working. 76.2% of the sample had the Dutch nationality and 20.5% had a different nationality (3.3% of the data were missing). Furthermore, 89.4% of the fathers and 87.7% of the mothers was born in the Netherlands.

5.2.2. Procedure
The study was conducted with the approval of the University of Amsterdam Review Board. Participants were recruited via four high schools around Amsterdam, from which active informed consent was obtained. Online questionnaires assessing all variables were administered in 2011. Two randomly selected students of each school received a 30 Euro gift voucher.

5.2.3. Measurements
5.2.3.1. Chronic sleep reduction
Chronic sleep reduction, reflecting symptoms of insufficient sleep, was measured using the CSRQ (Meijer, 2008). The 20-item CSRQ consists of four subscales: ‘Shortage of Sleep’ (6 items; e.g., ‘I am a person who does not get enough sleep’), ‘Irritation’ (5 items; e.g., ‘Others think that I am easily irritated’), ‘Loss of Energy’ (5 items; e.g., ‘I am active during the day’), and ‘Sleepiness’ (4 items; e.g., ‘Do you feel sleepy during the day?’) and refers to the previous two weeks. Each question has three ordinal response categories ranging from 1 to 3, with higher scores indicating more chronic sleep reduction. Consequently, the total CSRQ
scale consists of the sum of the four subscales. The CSRQ has recently been validated against five nights of school night sleep measured with actigraphy (Dewald, Short, Gradisar, Oort, & Meijer, 2012). Results from this study reveal that the CSRQ can be seen as a reliable (Cronbach’s alpha = .85) and valid measure of chronic sleep reduction in adolescents. Cronbach’s alpha for the total CSRQ scale in this study was .85.

5.2.3.2. Sleep duration

Participants were asked about their average bedtimes in the evening (indicated in hours and minutes), their average sleep onset latencies (indicated in hours and minutes), and their average waking up times (reported in hours and minutes) on school nights (Sunday to Thursday night) and on weekend nights (Friday and Saturday night). Sleep duration was defined as the difference between sleep onset (bedtime + sleep onset latency) and waking up time. We calculated the average sleep duration by combining sleep duration of school nights with sleep duration of weekend nights.

5.2.3.3. Sleepiness

Sleepiness was measured using a pediatric modification of the Epworth Sleepiness Scale (ESS) (Johns, 1991). In this eight-item questionnaire, adolescents rate on a four-point Likert scale (0: chance = not existing; 3: chance = big) how likely they are to doze in different situations (e.g., ‘Sitting and reading’; ‘Watching TV’). Various modifications have been used in pediatric populations (Anderson, Storfer-Isser, Taylor, Rosen, & Redline, 2009; Gibson et al., 2006). For this study, the last item ‘In a car while stopped for a few minutes in traffic’ was replaced with ‘Doing homework or taking a test’. This change was adapted from previous research (Anderson et al., 2009). The questionnaire is known to be a reliable and valid assessment tool for measuring sleepiness. The cut-off score for clinical sleepiness is highly discussed in the literature. Whereas originally a cut-off score of 10 has been suggested (Johns, 1997; Johns, 2002), some research recommends to use a higher cut-off score of 11 or 12 (Vignatelli et al., 2003). Cronbach’s alpha in this study was .80.

5.2.3.4. Depression

Depression was assessed with the Dutch version of the Children’s Depression Inventory (CDI) (Kovacs, 2002), which is based on the Beck Depression Inventory (BDI) (Beck, Ward, Mendelson, Mock, & Erbaugh, 1961) for adults. Most CDI items cover similar content and symptom areas, however, some additional items have been added to the CDI in order to cover areas of school, aggression, and other social-peer relations. The CDI includes 27 items, each consisting of three statements that are graded in severity (e.g., ‘I am sad once in
a while'; ‘I am sad many times’; ‘I am sad all the time’). The higher the assigned value (ranging from 0 to 2) the more severe the symptom is. The total score can range from 0 to 54. A cut-off score of 19 is used to indicate clinical depression. Cronbach’s alpha of the Dutch CDI version was .80 (Kovacs, 2002). Cronbach’s alpha in this study was .85.

5.2.3.5. Attention problems

Attention problems were measured with the attention problems subscale of the Youth Self-Report (YSR) (Verhulst, van der Ende, & Koot, 1997). This scale consists of nine items (e.g., ‘I find it difficult to concentrate and to keep paying attention’) which have to be rated on three-point Likert Scales. Cronbach’s alphas ranging from .57 to .68 have been found for different age groups in healthy children. A cut-off score of 11 is used to indicate a clinical score (Verhulst et al., 1997). Cronbach’s alpha in this study was .74.

5.2.3.6. School functioning

School functioning was operationalized with three separate constructs: ‘achievement motivation’, ‘teacher-child relationship’, and ‘academic self-concept’. Achievement motivation was measured with the subscale ‘achievement motivation’ of the Dutch PMT-K version (Hermans, 1983). This subscale consists of twelve closed-ended questions with two or three response categories (e.g., ‘Making my homework: A. is very annoying for me, B. I do not like it much, and C. I like doing’). The minimum score of this scale is 12, and the maximum score is 33. Cronbach’s alpha in this study was .81. Teacher-child relationship (e.g., ‘Our teacher is willing to help us when you do not understand something’), and academic self-concept (e.g., ‘I can keep up with others at school’) were measured with two scales of the School Perception Questionnaire (Meijer, Habekothe, & van den Wittenboer, 2000; van der Wolf, 1995). Both subscales consist of eight questions with five response categories (1 = completely true; 5 = not true at all). Cronbach’s alphas in this study were .80 and .88.

5.2.3.7. School performance

Participants were asked about the grades that they mostly receive at school (‘Which grade do you usually receive at school?’). Answers consisted of five categories ranging from ‘4 or lower’ (reflecting a clear ‘fail’ in the Netherlands) to ‘9/10’ (the highest grades that can be achieved in the Netherlands).

5.2.4. Analyses

To gain more insight into the idea of individual differences in sleep need, we started the analyses by identifying four extreme groups: (1) a group with high chronic sleep reduction
(highest quartile on the CSRQ) and short sleep duration (lowest quartile of sleep duration),
(2) a group with high chronic sleep reduction (highest quartile on the CSRQ) and long sleep
duration (highest quartile of sleep duration), (3) a group with low chronic sleep reduction
(lowest quartile on the CSRQ) and short sleep duration (lowest quartile of sleep duration),
and (4) a group with low chronic sleep reduction (lowest quartile on the CSRQ) and long
sleep duration (highest quartile of sleep duration). If individuals meet the criteria for group 2
or 3, the idea that individual differences in sleep need exist can be confirmed.

To capture the influence of sleep duration, we ran the following analyses for sleep
duration (lowest and highest quartile of sleep duration) and chronic sleep reduction (lowest
and highest quartile of the CSRQ) separately. For the two different sleep measures (sleep
duration and CSRQ scores) multivariate analyses of variances (MANOVAs) were used to
examine whether the two groups differed on daytime functioning. Furthermore, we calculated
the proportion of clinical cases in each group to identify individual differences in vulnerability
to sleep loss. Each MANOVA was followed by a discriminant function analysis to investigate
predictors of group membership (short versus long sleep duration, low versus high CSRQ
scores).

5.3. Results
To gain more insight into individual differences in sleep need, we identified the above-
described four groups, which combine chronic sleep reduction (measured by the CSRQ) with
sleep duration. Although most adolescents met the criteria for either group 1 (n= 191) or
group 4 (n=198), a smaller sample also met the criteria for group 2 (n=25) and group 3
(n=34). These results indicate that some adolescents experience symptoms of insufficient
sleep although they have long sleep durations and that some adolescents do not experience
such symptoms although they have short sleep durations. Consequently, this finding
supports the idea of individual differences in sleep need.

The following analyses were based on the extreme groups (using the upper and
lower quartiles) for chronic sleep reduction and sleep duration separately. Table 1 presents
means and standard deviations for these four extreme groups and for the total sample. In
comparison to the means of the total sample, daytime functioning of adolescents with high
chronic sleep reduction or short sleep durations was more impaired, whereas adolescents
with low chronic sleep reduction or long sleep durations had less daytime functioning
impairments. Furthermore, results from the MANOVAs demonstrate a significant overall
effect for sleep duration (F (7,405) = 16.43, p < .001) and chronic sleep reduction (F (7,452) =
62.99, p < .001) on daytime functioning.
Table 2 presents the proportion of clinical cases on depression, attention problems, and sleepiness in the different groups. Similarly to the above-described means, we found the highest proportion of clinical cases in the group of adolescents with high chronic sleep reduction and short sleep durations and the lowest proportion of clinical cases in the groups of adolescents with low chronic sleep reduction and long sleep durations.

Each MANOVA was followed up by a discriminant function analysis. Results from the analysis for chronic sleep reduction indicate depression to be the best discriminating factor (.77), followed by attention problems (.68), academic self-concept (-.61), achievement motivation (-.56), and sleepiness (.55). The teacher-child relationship (-.40) and school performance (-.24) were less strong predictors. Daytime functioning could classify 76.2% of the group correctly into the group with high chronic sleep reduction and 89.8% into the group with low chronic sleep reduction. However, we found a different picture for sleep duration, demonstrating that achievement motivation (.84) and attention problems (-.75) were the factors that could discriminate the best between adolescents with short and long sleep durations. These factors were followed by depression (-.67), academic self-concept (.67), the teacher-child relationship (.48), school performance (.35), and sleepiness (-.20). The factors identified 65.3% of the group with short sleep durations and 68% of the group with long sleep durations correctly.

5.4. Discussion
The present study is the first study that investigated individual differences in sleep need and vulnerability to sleep loss in adolescents. The results support previous findings that demonstrate the existence of individual differences in sleep need (Ferrara & De Gennaro, 2001; van Dongen et al., 2003) by showing that some adolescents experience symptoms of insufficient sleep despite obtaining much sleep, and, on the other hand, that some individuals with extremely short sleep durations do not report such symptoms. Based on these results, it can be concluded that sleep duration may not be the best indication of chronic sleep loss, as it does not account for individual differences in sleep need. Furthermore, we examined individual differences in vulnerability to sleep loss. We addressed this question by identifying the proportion of cases with poor outcomes in extreme groups and studied whether daytime functioning variables can discriminate between individuals with high and low chronic sleep reduction and long and short sleep durations. The findings from this study clearly demonstrate that daytime functioning is more (even clinically) impaired in adolescents with high chronic sleep reduction and adolescents with short sleep durations than the impairments that have been reported in the total sample.
Table 1. Means and standard deviations for the four extreme groups and the total sample

<table>
<thead>
<tr>
<th>Sleep Duration</th>
<th>Chronic sleep reduction (CSRQ)</th>
<th>Total sample (mean (SD))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short (mean (SD))</td>
<td>Long (mean (SD))</td>
<td>High (mean (SD))</td>
</tr>
<tr>
<td>Sleepiness</td>
<td>8.27 (5.02)</td>
<td>6.59 (4.46)</td>
</tr>
<tr>
<td>Depression</td>
<td>11.93 (6.78)</td>
<td>6.68 (5.84)</td>
</tr>
<tr>
<td>Attention problems</td>
<td>7.46 (3.24)</td>
<td>4.94 (3.02)</td>
</tr>
<tr>
<td>Achievement motivation</td>
<td>25.07 (4.10)</td>
<td>28.12 (3.89)</td>
</tr>
<tr>
<td>Teacher–child relationship</td>
<td>28.05 (4.32)</td>
<td>32.08 (5.03)</td>
</tr>
<tr>
<td>Academic self-concept</td>
<td>3.34 (.67)</td>
<td>3.56 (.60)</td>
</tr>
</tbody>
</table>

Table 2. Proportion of clinical cases for the four extreme groups and the total sample

<table>
<thead>
<tr>
<th>Sleep Duration</th>
<th>Chronic sleep reduction (CSRQ)</th>
<th>Total sample (% clinical cases)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sleepiness (clinical cut-off: ≥ 11)</td>
<td>29.11</td>
<td>20.5</td>
</tr>
<tr>
<td>Depression (clinical cut-off: ≥ 19)</td>
<td>11.27</td>
<td>2.50</td>
</tr>
<tr>
<td>Attention problems (clinical cut-off: ≥ 11)</td>
<td>16.90</td>
<td>3.00</td>
</tr>
</tbody>
</table>
On the other hand, adolescents with low chronic sleep reduction and long sleep durations show less impairments on the daytime functioning variables than the impairments that have been reported in the total sample. These results support the idea of individual differences in vulnerability to sleep loss. Furthermore, daytime functioning variables could more accurately discriminate between groups that were characterized by chronic sleep reduction than between groups that were characterized according to their sleep duration. This result indicates that symptoms of insufficient sleep may be a better conceptualization to capture the full picture of chronic sleep loss than sleep duration. The finding that a distinction based on sleep duration resulted in worse classifications may at least partly be ascribed to the fact that this concept does not include all aspects of sleep quality (e.g., satisfaction with sleep).

A few limitations have to be mentioned: First, we used a cross-sectional design, which does not allow causal conclusions. Second, all data were based on self-reports, whereas no objective data on sleep (e.g., actigraphy or polysomnography) and school performance (e.g., grades from school reports) were collected. However, considering the high diversity of measures and the consistent findings, common method variance should not negatively affect the results (Spector, 2006). Finally, the study should be replicated in other samples, preferably allowing for cross-cultural comparisons, in order to further generalize the reported results. Such studies should also include personality characteristics in order to capture the full picture of the possible phenotypes.

Summarizing, the present study showed that individual differences in sleep need exist. Furthermore, we demonstrated individual differences in vulnerability to sleep loss. The results indicate that studying the effects of sleep on daytime functioning by focusing on chronic sleep reduction rather than looking at sleep duration directly, gives a more accurate picture of the effects of sleep loss.
5.5. References


