Sleep in older adolescents. Results from a large cross-sectional, population-based study

Short title: Sleep in older adolescents

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SUMMARY

The aim of the present study was to describe sleep patterns in a large and representative sample of Norwegian adolescents. The sample included 4010 1st year high school students, aged 16-17 years (54% female), who completed a web-based survey on sleep patterns. The process of going to sleep was addressed as a two-step sequence of i) shuteye latency (interval from bedtime to shuteye time) and ii) sleep onset latency (interval from shuteye time to sleep onset). Results showed that 84.8% of the adolescents failed to obtain the recommended amount of sleep (8+ hours) on schooldays, and 49.4% obtained less than 7 hours. Mean bedtime on schooldays was 22:33, with rise time 08:19 hours later (time in bed). The adolescents reported long school day shuteye latency (43 minutes), limiting sleep opportunity to 07:36 hours. Sleep onset latency was 32 minutes and mean school day sleep duration was only 06:43 hours. On free days, 26.3% of the adolescents obtained less than 8 hours of sleep, and 11.7% obtained less than 7 hours. Mean bedtime was 00:33, time in bed was 10:35 hours, shuteye latency was 39 minutes and sleep onset latency was 24 minutes. Mean free day sleep duration was 08:38 hours. There were sex differences in several sleep parameters, including shuteye latency. The results indicate that the majority of Norwegian adolescents fail to obtain the recommended amount of sleep (8+ hours) on schooldays. Long shuteye latency appears to be a main driver for short school day sleep duration in adolescents.

Keywords: Shuteye latency, sleep duration, social jetlag

INTRODUCTION

Sufficient sleep is crucial to adolescent health, well-being and daytime functioning. Short sleep in adolescents is consequently associated with negative mental and somatic health outcomes, poor academic performance, school absence and poor health behaviors (Dewald, Meijer, Oort, Kerkhof, & Bogels, 2010; Hysing, Harvey, Linton, Askeland, & Sivertsen, 2016; Hysing, Haugland, Stormark, Boe, & Sivertsen, 2015; Owens & Weiss, 2017; Pasch, Laska, Lytle, & Moe, 2010; Saxvig, Pallesen, Wilhelmsen-Langeland, Molde, & Bjorvatn, 2012). Based on available scientific evidence, the US National Sleep Foundation in 2015 published recommendations that teenagers aged 14-17 years should obtain 8-10 hours of sleep each night (Hirshkowitz et al., 2015). However, research indicates that adolescents world-wide sleep less than this (Gariepy et al., 2020; Gradisar, Gardner, & Dohnt, 2011; Owens & Weiss, 2017).

According to the «perfect storm» model, biological and psychosocial factors interact to produce a social jetlag and curtail sleep in adolescents (Carskadon, 2011; Crowley, Wolfson, Tarokh, & Carskadon, 2018; Wittmann, Dinich, Merrow, & Roenneberg, 2006). During puberty, a biologically based shift towards eveningness and slower accumulation of sleep need (Andrade, Benedito-Silva, Domenice, Arnhold, & Menna-Barreto, 1993; Carskadon, Vieira, & Acebo, 1993; Jenni, Achermann, & Carskadon, 2005; Taylor, Jenni, Acebo, & Carskadon, 2005), act together with sleep related behaviors such as the use of electronic media and consumption of caffeinated beverages (Calamaro, Mason, & Ratcliffe, 2009; LeBourgeois et al., 2017) delaying sleep timing. Still, school start times usually remain early or unchanged (Carskadon, Wolfson, Acebo, Tzischinsky, & Seifer, 1998; Wheaton, Chapman, & Croft, 2016). Adolescents have large social jetlag compared to adults and younger children (Roenneberg, Allebrandt, Merrow, & Vetter, 2012), and their sleep pattern is characterized by late and short sleep on schooldays and late and longer sleep on free days (Gradisar et al., 2011). Attesting to the irregular adolescent school day – free day sleep pattern, Hysing and colleagues found that Norwegian adolescents had an average sleep duration of 06:25 hours on schooldays compared to 08:37 hours on free days (Hysing, Pallesen, Stormark, Lundervold, & Sivertsen, 2013). There are, however, discrepancies between studies in terms of sleep duration, the aforementioned study being at the lower end of what is commonly reported (Gradisar et al., 2011). This divergence may be related to cultural dissimilarities (e.g. bedtime norms and school start times) and/or differences in sample characteristics (e.g. age and sex), as well as methodological disparities (Gradisar et al., 2011; Hysing et al., 2013).

Previous studies on adolescent sleep have often measured time in bed (TIB) but rarely included detailed descriptions of wakefulness in bed, hence possibly overestimating sleep duration (Gradisar et al., 2011). In order to provide accurate estimates of sleep duration, it is necessary to account for sleep onset latency (SOL - the interval from attempting to go to sleep to sleep onset), wake after sleep onset (WASO - wakefulness during the sleep period) and early morning awakening (EMA – the interval from wakeup time to rise time). In their study, Hysing and colleagues accounted for SOL and WASO, but not for EMA (Hysing et al., 2013). Furthermore, they calculated SOL from reported bedtime, which likely yields an overestimation of this parameter since many adolescents will not attempt to go to sleep immediately upon bedtime. In line with this, Exelmans and colleagues have argued that preparing for sleep should be regarded as a two-step process of 1) deciding to go to bed (bedtime) and 2) deciding to go to sleep (shuteye time) (Exelmans & Van den Bulck, 2017). In a sample of 584 adults (18-96 years), they found longer shuteye latency (SEL, the interval from bedtime to shuteye time) in younger compared to older respondents, and noted that SEL was negatively associated with subjective sleep quality and positively associated with SOL and fatigue (Exelmans, Gradisar, & Van den Bulck, 2018). A two step process for wakefulness in bed may be especially relevant for adolescents given the documented long interval from bedtime to sleep onset during this age period (Hysing et al., 2013). Thus, it seems important to record shuteye time and to distinguish clearly between SEL and SOL when assessing and describing sleep. To our knowledge, no previous study has specifically addressed SEL in adolescents.

Most previous research has indicated that adolescent boys have later sleep, larger social jetlag and shorter sleep duration than girls the same age (Adan & Natale, 2002; Hysing et al., 2013; Natale, Adan, & Fabbri, 2009; Ohayon, Roberts, Zulley, Smirne, & Priest, 2000; Olds, Blunden, Petkov, & Forchino, 2010; Randler, Vollmer, Kalb, & Itzek-Greulich, 2019), but findings are not univocal (Chung & Cheung, 2008; Ohayon et al., 2000).

In the present study we aimed to describe sleep in a large and representative sample of high school students aged 16-17 years, by using a questionnaire that allowed for detailed assessment of wakefulness in bed (SEL, SOL, WASO, EMA) as well as school day – free day differences in sleep (including social jetlag). Further, we aimed to address possible sex differences in adolescent sleep.

METHODS

During spring 2019, all 1st year high school students in Hordaland and Rogaland counties in Norway were invited to participate in a web-based survey on sleep and health. The survey was technically administered by SurveyXact (Rambøll Management Consulting AS). Students in Hordaland received the invitation through the schools' electronic communication platform, whereas students in Rogaland were invited by their respective school administrations through email or SMS. The invitation contained information about the study and eligibility criteria (1st year high school students with age ≥ 16 years), as well as a link to the survey. The school administrations in both counties were encouraged by their respective regional school authorities to inform their students about the study and to allocate one school hour to complete the survey.

Ethics

The survey included an electronic informed consent form with 1) detailed information about the study and eligibility criteria; 2) confirmation (are you 16 years or older; yes/no); 3) consent (do you consent to participate in the study; yes/no), and an identification form (social security number, email-address, mobile number). Norwegian regulations state that individuals aged 16 years and older can consent themselves. The study was approved by the Regional Committee for Medical and Health Research Ethics (REK sør-øst 2019/110) and the Norwegian Centre for Research Data (NSD number 758174).

Sample

Based on information from the respective schools, the total number of 1st year high school students in the two counties was 11574. Altogether 4863 students provided consent to participate and the required personally identifiable information, yielding a response rate of 42.0%. In the present study we report sleep data from students born in 2002 (83.2% of the students who responded). Based on preliminary analyses, data from 36 students with obvious invalid responses (reporting negative sleep duration either on schooldays or free days) were omitted from the analyses. Hence, the final sample comprised 4010 1st year high school students aged 16-17 years.

Representativeness

Norway is a country in the northern part of Europe, stretching from 57ºN to 71ºN. Hordaland and Rogaland are neighbouring counties located on the western coast (58ºN to 61ºN). Data were collected from medio April (sunrise around 06:30, sunset around 21:00) through June (sunrise around 04:30, sunset around 23:00). At the time of data collection, about one fifth of the Norwegian population (998 021 of 5 328 212) lived in these two counties, being the 4th and 5th largest in Norway (18 in total). About half the inhabitants in these counties lived in or in proximity to one of the four large cities (Bergen, Stavanger, Sandnes and Haugesund). Although the overall response rate in the present study was 42%, there were, large discrepancies between schools in terms of response rate, suggesting systematic differences in management at the school level (invitation, information and facilitation) rather than selection bias at the individual level. The two counties had a total of 58 high schools, with the number of 1st year students on each school ranging from 30 to 670. All schools were approached by a member from the research team and the regional school authorities and encouraged to facilitate participation. A total of 11 schools had a response rate less than 20% (4 had response rate less than 5%), leading us to believe that students on these schools were not encouraged by their school administrations to respond to the survey during class hours. A total of 25 schools had response rates of 50% or more.

Instruments

Sociodemographic variables

All participants reported sex (male, female), date of birth and maternal and paternal education level [five response options: primary/secondary school; high school; college/university (<4 years); college/university (4+ years); I do not know].

Sleep

The sleep habits questionnaire included the Munich Chronotype Questionnaire (MCTQ) (Roenneberg, Wirz-Justice, & Merrow, 2003), asking about habitual bedtime, shuteye time (ST), sleep onset latency (SOL), wake up time (WUT) and early morning awakening (EMA, interval from WUT to rise time), for school days and free days separately. The Norwegian version of the MCTQ was adapted for children/adolescents for the purpose of the present study, based on the English version of the MCTQ for children/adolescents (www.thewep.org). In addition to the MCTQ, the survey included items measuring wake after sleep onset (WASO, time spent awake during the sleep period) on school days and free days, respectively: "For how long are you awake during the night on schooldays/free days?". All responses were provided on drop-down menus, time items on 15-minute interval scales (bedtime and shuteye time option ranged from 20:00 to 08:00; wake up time option ranged from 05:00 to 17:00), and latency/duration items (e.g. SOL, WASO) on 5-minute interval scales (option ranged from 0 minutes to 5 hours). Based on these data, we could calculate time for sleep onset (ST + SOL), rise time (WUT + EMA), time in bed (TIB, the interval from bedtime to rise time), shuteye latency (SEL, the interval from bedtime to ST), sleep opportunity (the interval from

ST to rise time), sleep period (SP, the interval from sleep onset to WUT), midsleep (MS = sleep onset + SP/2), sleep duration (SP - WASO), and sleep efficiency (SE = sleep duration/sleep opportunity x 100%) for school days and free days, respectively. We also calculated social jetlag ($MS_{free\ days} – MS_{school\ days}$). Based on the recommendations by the US National Sleep Foundation, sleep duration on school days was categorized into 8+ hours (recommended), 7-8 hours (may be appropriate) and <7 hours (not recommended) (Hirshkowitz et al., 2015).

To address how the adolescents perceived their sleep, they were also asked how much sleep they believed adolescents (16-19 years) need, with responses provided on a drop-down menu with 30-minute intervals: “How much sleep do you believe adolescents (16-19 years) need?”. They were also asked if they felt they obtained enough sleep on schooldays and free days, respectively, responses on a Likert scale (“far too little”, “too little”, “adequate”, “too much” and “far too much”): “Do you feel that you obtain enough sleep on schooldays/free days?”.

Statistics

IBM SPSS Statistics 25 (SPSS Inc., Chicago, Ill) was used for statistical analyses. A total of 3967 students (99%) completed all the sleep items. Each analysis was conducted with those who had responded to the item in question, hence the sample size varied slightly between the different parameters. Two-way ANOVAs (time x sex) were performed to examine effects of time (school day vs. free day) and sex (girls vs. boys) on sleep parameters. Significant effects of sex/interaction effects were followed up by independent samples t-tests (girls vs. boys on schooldays and free days, separately). In terms of social jetlag and sleep perception, differences between the sexes were investigated using independent samples t-tests (continuous variables) and chi-square analyses (Likert scale items).

RESULTS

Demographics are displayed in Table 1. A total of 54.0% of the adolescents were female (46.0 male), and 62.4% were 16 years old (37.6% were 17 years old).

[Insert Table 1 about here]

School day and free day sleep parameters are summarized in Table 2, overall as well as broken down by sex. Mean sleep duration was 6 hours and 43 minutes on schooldays, with 84.8% of the adolescents obtaining less than 8 hours of sleep and 49.4% obtaining less than 7 hours (see Figure 1 for distribution of sleep durations). On free days, mean sleep duration was 8 hours and 38 minutes, with 26.3% obtaining less than 8 hours of sleep, and 11.7% obtaining less than 7 hours. Girls had longer sleep duration than boys on free days (10 minutes difference), but not on schooldays.

[Insert Figure 1 about here]

Mean bedtime was 2 hours later on free days than on schooldays (00:33 vs. 22:33), whereas wake up time was 3 hours and 41 minutes later on free days than on schooldays (10:22 vs. 06:41). Accordingly, the adolescents had shorter TIB on schooldays (8 hours and 19 minutes) than they did on free days (10 hours and 35 minutes). Boys had later sleep timing than girls, both on schooldays and on free days, and they had shorter TIB (7 minutes difference on schooldays, 34 minutes difference on free days). The adolescents had a mean shuteye latency (SEL) of 43 minutes on schooldays and 39 minutes on free days. Sleep onset latency (SOL) was longer on schooldays (32 minutes) than on free days (24 minutes), hence the total interval from bedtime to sleep onset (SEL + SOL) was 1 hour and 15 minutes on schooldays and 1 hour and 3 minutes on free days. SEL was longer in girls than boys both on schooldays (7 minutes difference) and on free days (11 minutes difference), whereas SOL did not differ between the sexes. In general, the adolescents reported little wake during the sleep period (WASO), albeit slightly longer WASO on schooldays (8 minutes) than on free days (6 minutes). The ANOVA revealed no overall effect of sex on WASO. The adolescents had shorter interval from wake-up time to rise time (EMA) on schooldays (11 minutes) than on free days (46 minutes), and girls had longer EMA than boys on free days (13 minutes difference).

Mean sleep efficiency was generally within the range of what is considered normal (>85%), and higher on schooldays (88.2%) than on free days (87.2%). On free days, girls had slightly lower sleep efficiency than boys. The mean social jetlag was 2 hours 43 minutes (SD = 68 min), and larger in boys (2 hours and 51 minutes, SD = 75 min) than in girls (2 hours and 37 minutes, SD = 59 min, $p<.001$).

[Insert Table 2 about here]

Table 3 summarizes the adolescents sleep perceptions, overall and for girls and boys separately. On average, the reported adolescent sleep need was 8 hours and 11 minutes, with girls estimating a slightly larger adolescent sleep need than boys. A total of 50.6% reported obtaining too little or far too little sleep on schooldays, 48.6% reported obtaining adequate sleep and only 0.8% felt they slept too much or far too much. On free days, only 6.6% reported obtaining too little or far too little sleep, 81.1% reported obtaining adequate sleep and 12.4% reported obtaining too much or far too much sleep.

[Insert Table 3 about here]

DISCUSSION

Results from the present study showed that 16 to 17-year-olds attending Norwegian high schools had a mean school day sleep duration of 6 hours and 43 minutes, with 84.8% of the adolescents obtaining less than 8 hours of sleep and 49.4% obtaining less than 7 hours. Mean time in bed on school days was 8 hours and 19 minutes. The latter can be considered relatively appropriate in relation to current recommendations that adolescents 14-17 years should obtain 8+ hours of sleep each night (Hirshkowitz et al., 2015). Thus, the long shuteye latency of 43 minutes appeared to be a main driver behind the short school day sleep duration, by limiting sleep opportunity to 7 hours and 36 minutes.

On free days, sleep was later and longer (free day sleep duration 8 hours and 38 minutes), amounting to a social jetlag of 2 hours and 43 minutes. Boys had later and shorter sleep than girls, as well as a larger social jetlag.

The sleep durations in the present study are comparable to what was reported in a previous Norwegian study of high school students by Hysing and colleagues (Hysing et al., 2013), but in the lower end of what has been found in other European, American and Asian countries (Gariepy et al., 2020; Gradisar et al., 2011). Short sleep duration in Norwegian high school students is unlikely to reflect early school start times, since school does not start particularly early in Norway (usually between 08:00 and 08:30). The short sleep durations found in these Norwegian studies are more likely a function of the age ranges in question (older adolescents), since school day sleep duration tends to decrease across adolescence and increase during early adulthood (Gradisar et al., 2011). This assumption is supported by a study showing longer sleep duration in young adults, using the same assessment method as Hysing and colleagues (Hysing et al., 2013; Sivertsen et al., 2019). The finding of short sleep durations may also reflect methodological aspects, as differences in methods significantly affect the findings (Gradisar et al., 2011). Many previous studies have recorded time in bed, but failed to account for sleep onset latency (SOL), wake after sleep onset (WASO) and/or early morning awakening (EMA), and may consequently have overestimated sleep duration (Gradisar et al., 2011). The large discrepancies between time in bed (08:19 hours on schooldays), sleep opportunity (07:36 hours on schooldays) and sleep duration (06:43 hours on schooldays) found in the present study, clearly show that items on bedtime and rise time alone are imprecise when measuring sleep duration in adolescents. Despite relatively adequate TIB (8+ hours), the mean SEL of 43 minutes limited sleep opportunity to approximately 7 and a half hour in the present study, which is too short to obtain the recommended amount of sleep. SOL, WASO and EMA were close to what can be considered normal (American Academy of Sleep Medicine, 2014). Hence, SEL appeared to comprise the most important individual factor contributing to short school day sleep duration in the present sample. The long SEL found in the present study is in accordance with a previous report in young adults (Exelmans et al., 2018).

In the study by Hysing and colleagues, SOL was prolonged compared to what is usually considered normal (American Academy of Sleep Medicine, 2014; Hysing et al., 2013). This finding was only partially supported by the present study. In the study by Hysing and colleagues, however, SOL was defined as the interval from bedtime to sleep onset, which is equivalent to the combined SEL + SOL reported in the present study. In that regard, the combined SEL + SOL of 75 and 63 minutes (schooldays and free days, respectively) found in the present study were actually longer compared to the findings by Hysing and colleagues (Hysing et al., 2013). Both long SEL and SOL may be consequences of inability to fall asleep (e.g. due to early bedtimes in relation to the endogenous sleep drive). Still, the present study indicates that SEL was long also on free days when bedtimes were later. Thus, it is possible that SEL, to a large degree, reflects behaviors that are common in young people, such as electronic media usage in bed (Fossum, Nordnes, Storemark, Bjorvatn, & Pallesen, 2014). Electronic media usage in bed may contribute to delayed sleep onset both by direct displacement of sleep time and by affecting SOL (e.g., alertness due to light exposure, cognitive and emotional arousal) (Hale & Guan, 2015). Future studies should look further into the causal relationship between activities in bed, shuteye latency and sleep timing in adolescents.

In terms of social jetlag, the result from the present study (2 hour and 43 minutes) is in line with the school day – free day discrepancy in bedtime reported in a meta-analysis (Gradisar et al., 2011), and larger than what has been reported in adult populations (Randler, 2011; Randler et al., 2019; Roenneberg et al., 2012). Sleep and social jetlag also appeared to differ between the sexes. Although not univocal, most previous research has indicated that adolescent boys have later sleep, more social jetlag and shorter sleep duration than girls the same age (Adan & Natale, 2002; Chung & Cheung, 2008; Hysing et al., 2013; Natale et al., 2009; Ohayon et al., 2000; Olds et al., 2010; Randler et al., 2019). The present study largely supports these previous findings. However, girls had more wakefulness in bed, so despite the fact that they spent more time in bed sleep duration in girls was significantly longer than that in boys only on free days. Interestingly, sleep deficiency and social jetlag have been demonstrated to affect girls more than boys, possibly due to a greater sleep need in girls (although also other mechanisms have been suggested) (Cespedes Feliciano et al., 2019; Henderson, Brady, & Robertson, 2019; Hysing et al., 2013). This notion seems to be supported by the present study, as girls estimated a higher adolescent sleep need than boys.

It is worrying that as many as 85% of the adolescents failed to meet the recommendations of 8+ hours of sleep on school days, given the established relationship between short sleep duration, poor mental and somatic health and poor academic performance in adolescents (Dewald et al., 2010; Hysing et al., 2016; Hysing et al., 2015; Owens & Weiss, 2017; Pasch et al., 2010; Saxvig et al., 2012). Interestingly, studies have indicated that adolescents may be aware of current sleep recommendations (Hysing et al., 2013), but that this knowledge is not corroborated behaviorally (Cain, Gradisar, & Moseley, 2011). This seemed to be the case also in the present study, as the respondents on average estimated an adolescent sleep need a little more than 8 hours. It is of note that almost half the respondents still claimed that they obtained adequate amounts of sleep on schooldays. There are several possible explanations for this apparent contradiction. First, adolescents may feel that they obtain adequate sleep while still suffering from sleep curtailment. Sleep is only one of the factors contributing to alertness, and many adolescents may be able to function well throughout the day through motivation, socializing, light exposure, caffeine consumption and activity (Hayashi, Masuda, & Hori, 2003; Oken, Salinsky, & Elsas, 2006). Second, it is possible that the short sleep duration measured by MCTQ reflects a recall bias. Although the adolescents may be able to estimate time in bed quite accurately (they know when they went to bed and rose in the morning), they may be poorly able to estimate their shuteye latency and thus underestimate their sleep duration (for example they may remember spending much time on their mobile phones before trying to go to sleep, but not how much). Third, as we did not account for napping, which many adolescents do, the nocturnal estimates reported in the present study may represent underestimates of the total daily sleep duration. A fourth possibility is that adolescent sleep need is overestimated. The recommendations of the NSF (Hirshkowitz et al., 2015) are based on observational studies and expert opinions, and are still being debated (Chaput et al., 2016; Sawyer, Heussler, & Gunnarsson, 2019). The assumed sleep need reported by the adolescents in the present study may be based on what they have learned about sleep in addition to their own experiences.

The findings in the present study may have implications for future intervention programs aiming to promote sleep in adolescents. When addressing nighttime routines, there may be little to gain by focusing on advancing bedtimes, since time in bed already appear to be relatively adequate (8+ hours), possibly due to social norms and parental involvement. Thus, sleep intervention programs may have more to gain by focusing on shuteye parameters, which may be less subjected to parental involvement, for example by focusing on how the shuteye time affects sleep opportunity and how activities during the shuteye interval (e.g. electronic media usage in bed) may promote alertness. The finding of a long shuteye latency during weekends, when bedtimes are later, indeed suggests that mechanisms other than sleep drive may influence shuteye time and the duration of the shuteye interval, making it a suitable target for intervention.

Strengths and limitations

The strengths of the present study include a relatively large, population-based sample and the use of a validated questionnaire to address sleep and social jetlag. MCTQ measures sleep on schooldays and free days separately, which is of crucial importance when investigating adolescent sleep. The thorough assessment of wakefulness in bed (SEL, SOL, WASO and EMA) represents a major strength, as it enabled a more detailed assessment of sleep patterns and duration as compared to many previous studies. In particular, the distinction between SEL and SOL seems important. The long SEL found in the present study suggest that it is a useful parameter in survey studies when addressing sleep patterns in adolescents, in particular since activities in bed after bedtime may not only displace sleep but also promote alertness and as such affect the ability to fall asleep. We thus recommend that future studies on sleep in adolescents report both SEL and SOL. To our knowledge, the present study is the first in adolescents toreport shuteye latency (SEL).

The present study has some limitations that should be kept in mind when interpreting the data. All data were self-reported and not corroborated by objective measures, which is not feasible in large-scale studies. The survey did not include items on parental involvement with respect to bedtimes and shuteye times, limiting our ability to interpret these data in a psychosocial context. Shuteye time is routinely reported when performing sleep recordings (polysomnography, actigraphy and sleep diaries), as the reference point from which time in bed is measured and sleep efficiency calculated, whereas shuteye latency is usually not reported. The validity of items on shuteye time and latency in survey studies has not yet been investigated. In the studies by Exelmans and colleagues, respondents were asked to estimate shuteye latency (Exelmans et al., 2018; Exelmans & Van den Bulck, 2017), whereas respondents in the present study were asked to estimate shuteye time. In order to address the reliability and validity of shuteye items (time, latency), we suggest validating these items against simultaneous, objective sleep recordings. In terms of representativeness only high school students were invited to participate and the findings may not be generalizable to adolescents not attending school.

Conclusion

The current results support the world-wide finding that the majority of older adolescents fail to obtain sufficient sleep on schooldays. Interestingly, time spent in bed was relatively adequate in relation to current recommendations (8+ hours), however long shuteye latency significantly limited the adolescents sleep opportunity. Thus, shuteye latency appears to be a main driver for short school day sleep durations. The findings may have implications for future intervention programs aimed to promote sleep in adolescents.

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Table 1. Sample characteristics (n=4010)

	N (%)
Sex	
Female	2165 (54.0%)
Male	1845 (46.0%)
Age	
16 years	2504 (62.4%)
17 years	1506 (37.6%)
County	
Hordaland	1827 (45.6%)
Rogaland	2183 (54.4%)
Maternal education	
Primary/secondary school	206 (5.1%)
High school	740 (18.5%)
College/university (<4 years)	784 (19.6%)
College/university (4+ years)	1417 (35.3%)
Do not know	863 (21.5%)
Paternal education	
Primary/secondary school	263 (6.6%)
High school	996 (24.8%)
College/university (<4 years)	621 (15.5%)
College/university (4+ years)	1190 (29.7%)
Do not know	940 (23.4%)

Table 2. Detailed description of school day vs. free day sleep in adolescents aged 16 to 17 years, overall and by sex (n=3972).

	Total (n = 3972)		Girls (n = 2149)		Boys (n = 1823)		**Two-way ANOVAs (p-value)**		
	Schooldays	**Free days**	Schooldays	Free days	Schooldays	Free days	**Time**	**Sex**	**Interaction**
SLEEP TIMING (hh:mm)									
Bedtime	**22:33 ± 55**	**00:33 ± 83**	22:24 ± 53	00:13 ± 74	22:44 ± 56*	00:56 ± 88*	**<.001**	**<.001**	**<.001**
Shuteye time	**23:16 ± 61**	**01:12 ± 83**	23:11 ± 59	00:57 ± 76	23:23 ± 62*	01:29 ± 88*	**<.001**	**<.001**	**<.001**

Midsleep	**03:15 ± 46**	**05:59 ± 81**	03:09 ± 42	05:46 ± 72	03:23 ± 49*	06:14 ± 88*	**<.001**	**<.001**	**<.001**
Wake up time	**06:41 ± 36**	**10:22 ± 92**	06:35 ± 33	10:11 ± 82	06:49 ± 38*	10:34 ± 101*	**<.001**	**<.001**	**.004**
Rise time	**06:53 ± 38**	**11:08 ± 102**	06:46 ± 34	11:04 ± 94	07:00 ± 41*	11:14 ± 111*	**<.001**	**<.001**	**.281**
WAKEFULNESS IN BED (hh:mm)									
Shuteye latency	**00:43 ± 54**	**00:39 ± 57**	00:46 ± 56	00:44 ± 60	00:39 ± 51*	00:33 ± 52*	**<.001**	**<.001**	**.030**
Sleep onset latency	**00:32 ± 49**	**00:24 ± 48**	00:32 ± 44	00:23 ± 42	00:33 ± 54	00:24 ± 53	**<.001**	**.520**	**.684**
Wake after sleep onset	**00:08 ± 24**	**00:06 ± 23**	00:09 ± 22	00:06 ± 19	00:07 ± 25*	00:06 ± 26	**<.001**	**.115**	**.032**
Early morning awakening	**00:11 ± 13**	**00:46 ± 41**	00:11 ± 13	00:52 ± 43	00:10 ± 14	00:39 ± 37*	**<.001**	**<.001**	**<.001**
SLEEP DURATION (hh:mm)									
Time in bed	**08:19 ± 58**	**10:35 ± 100**	08:22 ± 58	10:51 ± 96	08:15 ± 58*	10:17 ± 101*	**<.001**	**<.001**	**<.001**
Sleep opportunity	**07:36 ± 61**	**09:56 ± 92**	07:35 ± 61	10:06 ± 88	07:36 ± 62	09:44 ± 95*	**<.001**	**<.001**	**<.001**
Sleep duration	**06:43 ± 87**	**08:38 ± 98**	06:42 ± 83	08:43 ± 93	06:44 ± 91	08:33 ± 104*	**<.001**	**.093**	**<.001**
SLEEP EFFICIENCY (%)									
Sleep efficiency	**88.2 ± 14**	**87.2 ± 12**	88.0 ± 13	86.5 ± 11	88.4 ± 15	88.0 ± 13*	**<.001**	**.014**	**.001**

*p<.05 independent samples t-test between sexes.

Table 3. Sleep perceptions in adolescents aged 16 to 17 years.

	Total	Girls	Boys	P-value
How much sleep do you believe adolescents (16-19 years) need? (n = 3874)				
Estimated adolescent sleep need	08:11 ± 73	08:14 ± 60	08:08 ± 86	.010 (t-test)
Do you feel you obtain enough sleep on schooldays? (n = 3982)				
Far too little	510 (12.8%)	323 (15.0%)	187 (10.2%)	<.001 (chi-square)
Too little	1506 (37.8%)	910 (42.2%)	596 (32.6%)	

Adequate	1935 (48.6%)	913 (42.4%)	1022 (55.9%)	
Too much	22 (0.6%)	7 (0.3%)	15 (0.8%)	
Far too much	9 (0.2%)	2 (0.1%)	7 (0.4%)	
Do you feel you obtain enough sleep on free days? (n = 3962)				
Far too little	47 (1.2%)	28 (1.3%)	19 (1.0%)	<.001 (chi-square)
Too little	192 (4.8%)	113 (5.3%)	79 (4.4%)	
Adequate	3150 (79.5%)	1741 (81.1%)	1409 (77.6%)	
Too much	483 (12.2%)	235 (11.0%)	248 (13.7%)	
Far too much	90 (2.3%)	29 (1.4%)	61 (3.4%)