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Original Article

Circadian typology and implications for adolescent sleep health. Results from a large, cross-sectional, school-based study

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ABSTRACT

Study objectives: To investigate circadian typology in a large, representative sample of Norwegian adolescents, and its implications for sleep health.
Methods: The sample included 3920 1st year high school students aged 16–17 years. Respondents completed a web-based survey, including the short version of the Horne-Ostberg Morningness-Eveningness Questionnaire (rMEQ), the Munich Chronotype Questionnaire (MCTQ) and items on sleep-related behaviors (eg electronic media usage in bed, consumption of caffeinated beverages), sleep beliefs and daytime sleepiness. Data were analyzed using one-way ANOVAs and Chi-squared tests.
Results: In all, 7.8% were categorized as morning, 52.3% as intermediate and 39.9% as evening types, respectively. Evening types had later sleep timing, longer sleep latency, more social jetlag and shorter school day sleep duration than morning types, with intermediate types displaying a sleep pattern between these two extremes. None of the circadian types met the minimum recommended amount of sleep on school nights (ie 8+ hours), and only morning types had a mean sleep duration of 7+ hours (7:19 h, nearly 1 h more than evening types who slept 6:20 h, $p < 0.001$). Evening types reported more use of electronic media in bed, more consumption of caffeinated beverages and more daytime sleepiness than the other circadian types. They were also less satisfied with their school day sleep duration and perceived it more difficult to change their sleep pattern.
Conclusions: Results from this study suggest that eveningness represents a sleep health challenge for older adolescents.

1. Introduction

Circadian typology reflects the chronobiological phenotypes that arise from individual variations in circadian timing. Measured either in terms of diurnal preference (temporal preference for sleep and activity, eg morningness-eveningness questionnaires) [1] or in terms of chronotype (behavioral patterns for sleep and activity, eg midsleep on free days) [2], individuals are typically classified either as morning, intermediate or evening types. Compared to intermediate types, morning types have earlier and evening types later, preference and timing for sleep and activity. Circadian typology is generally considered an individual trait with a genetic basis [3]. It is, however, affected by external factors and changes across the lifespan with maximal eveningness at the end of puberty [3–9].

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Whereas the distribution of circadian types is about 20% morning, 60% intermediate and 20% evening types in the general population [3], a “Sleep in America” poll found 15 years ago that 56% of adolescents from 6th to 12th grade considered themselves “night owls” (≈evening type) [10]. This poll, however, did not include a validated questionnaire on circadian typology, and it was conducted prior to the introduction of smartphones [11]. The prevalence of self-classified “night owls” is likely to be higher than the prevalence of evening types as identified through validated questionnaires on circadian typology. Indeed, more recent studies using validated questionnaires in adolescents and young adults have yielded lower, albeit somewhat inconsistent, prevalence rates. For example, using the short version of the Morningness-Eveningness Questionnaire (rMEQ) [1,12], Urban and colleagues found a distribution of circadian types amounting to about 30% morning and 20% evening types among Hungarian adolescents [13], whereas Li and colleagues found a distribution of circadian types closer to 10% morning and 20% evening types among adolescents in Hong Kong [14]. In a slightly older Swedish sample, Danielsson and colleagues found rates of approximately 10% morning and 30% evening types [15]. These discrepancies may in part reflect methodological disparities, for example, the criteria used to classify circadian types. Moreover, the distribution of circadian types is likely sample-specific, and discrepancies between studies may thus reflect differences in age, culture, latitude of residence and gender [5–8]. Hence, there is a need for studies addressing the distribution of circadian typology in large and age-specific, population-based samples, using validated questionnaires with predetermined cut-off criteria enabling comparison across studies.

The trans-pubertal drift towards eveningness significantly affects sleep in adolescents, not only directly through later biological timing for sleep but also indirectly through behaviors that may induce or exacerbate late sleep timing. In an interplay with early morning obligations, evening types tend to experience a larger social jetlag (difference between midsleep on school/work days and free days), characterized by shorter school-/workday sleep durations and longer free day sleep durations, compared to the other circadian types [3,16]. Moreover, attempting to adhere to socially acceptable sleep schedules, evening types may more often go to bed before they are ready for sleep, resulting in prolonged sleep latency compared to the other circadian types [17]. Electronic media usage is common among adolescents [18], and wakefulness in bed may promote media usage in bed (“*I can't fall asleep, so I might as well use my mobile*”) [19]. Conversely, electronic media usage may contribute to late sleep timing, both by displacing sleep and by inducing alertness [20,21]. While one study did not find an association between circadian typology and media usage [22], others have reported media usage to differ across circadian types in adolescents and young adults, with lower media use in morning types [13,23,24]. Another sleep-related behavior that is common during adolescence and which appears to be associated with circadian typology, is consumption of caffeinated beverages (eg energy drinks, coffee), possibly as a means for staying alert or overcoming daytime sleepiness [25–27]. However, caffeine consumption across the day may accumulate and induce alertness in the evening, impairing the ability to fall asleep [26,27].

Eveningness is associated with increased risk for mental disorders, as well as impaired daytime functioning [3,28]. These associations may in part be explained by short sleep duration (ie school day sleep curtailment) [29–34], although circadian mechanisms (ie the synchrony effect ~ circadian variations in performance and alertness) [35,36] and personality traits associated with eveningness (eg low conscientiousness) [3,37] appear to have sleep-independent effects on health and daytime functioning. Moreover, it is likely that these factors may mutually influence each other. For example, circadian phase and personality traits may represent barriers against successful sleep health interventions in evening type adolescents [3,37,38]. Interestingly, adolescent sleep beliefs appear to differ in relation to circadian typology, with evening type adolescents scoring lower on sleep knowledge scales than the other circadian types and also reporting more sleep dissatisfaction [39,40]. Thus, it seems important to take circadian typology into consideration when addressing adolescent sleep health [41].

In the present study, we aimed to describe the contemporary distribution of circadian types in a large and representative sample of high school students aged 16–17 years, by using a validated questionnaire on circadian typology (rMEQ) with pre-determined cut-off criteria. We further aimed to describe sleep patterns, sleep-related behaviors (electronic media usage, consumption of caffeinated beverages), daytime sleepiness and sleep beliefs in relation to circadian typology. We hypothesized that i) the prevalence of eveningness would be higher (>30%) than the 20% that is commonly reported in adult samples, and that, compared to the other circadian types, evening types would report: ii) later sleep timing, larger social jetlag, shorter school day sleep duration and longer sleep latency; iii) more behaviors that may be associated with late sleep timing (electronic media usage in bed and consumption of caffeinated beverages); iv) more daytime sleepiness and impaired daytime functioning, and; v) more sleep dissatisfaction (not feeling that they obtain enough sleep on schooldays), as well as more perceived problems advancing their sleep pattern towards earlier bed- and rise times.

2. Methods

From April through June 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 [42]. Students in Hordaland received the invitation via their school's electronic communication platform, whereas students in Rogaland were invited via 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 survey included an electronic consent form in which participants confirmed that they were 16 years or older and that they consented to participate. 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.

2.1. Ethics

The electronic informed consent was obtained after the participants had received detailed written information about the study. Norwegian regulations state that individuals aged 16 years and older can provide consent themselves. The study was approved by the Regional Committee for Medical and Health Research Ethics (REK south-east 2019/110) and the Norwegian Centre for Research Data (NSD number 758174).

2.2. Sample

Based on information from the respective schools, the total number of 1st year high school students in the two counties was 11,574. Altogether, 4863 students consented to participate, yielding a response rate of 42%. In order to reduce the influence of age, we only report data from students born in 2002 (83.2% of the students that responded to the study). Data from 93 students that had not responded to the MCTQ and 33 students with invalid responses (reporting negative sleep duration either on school days or free days) were omitted from the analyses. The final sample thereby comprised a total of 3920 1st year high school students, out of which 54.4% were female (45.6% were male) and 62.4% were 16 years old (37.6% were 17 years old).

2.3. Setting

Hordaland and Rogaland are neighbouring counties located on the western coast of Norway (58°N to 61°N). Data were collected from mid-April (sunrise around 6:30 AM, sunset around 21:00 PM) to June (sunrise around 4:30 AM, sunset around 23:00 PM). High school students in Norway normally attend school from Monday through Friday, and mean self-reported school start time in the sample was at 08:13 ± 17 min. A total of 89.5% reported a school start time between 8:00 and 8:30. Further details on the study setting are described in a previous publication [42].

2.4. Instruments

2.4.1. Circadian typology

Circadian preference was measured using the short version of the Horne-Ostberg Morningness-Eveningness Questionnaire (rMEQ) [1,12]. The rMEQ is a brief 5-item questionnaire that has been shown to correlate well with other measures of circadian typology [43]. Scores range from 4 to 26, with higher scores indicating more morningness. For the present study, each respondent was classified as either morning, intermediate or evening types based on the following cut-offs: morning types >17, intermediate types 12–17, and evening types <12 [12,15]. Cronbach's alpha for rMEQ was 0.54 in the present study, and mean inter-item correlation was 0.20.

2.4.2. Sleep

The online questionnaire included the Munich ChronoType Questionnaire (MCTQ) [2], asking about habitual bedtime (BT), time of preparing to sleep (here referred to as shuteye time, ST), sleep latency (here referred to as sleep onset latency, SOL), sleep end (here referred to as wake up time, WUT) and sleep inertia (interval from WUT to rise time, here referred to as early morning awakening, EMA), 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. All responses were provided through drop-down menus, with clock time items on 15-min interval scales (BT and ST option ranged from 20:00 to 08:00, WUT option ranged from 05:00 to 17:00) and latency/duration items (SOL, WASO, EMA) on 5-min interval scales from 0 min to 5 h. Based on BT, ST, WUT, EMA and WASO, we calculated rise time (RT = WUT + EMA), shuteye latency (SEL, the interval from BT to ST), sleep opportunity (the interval from ST to RT), sleep period (SP, the interval from sleep onset to WUT), midsleep (MS = sleep onset + SP/2) and sleep duration (SP - WASO), for school days and free days, respectively. We also calculated social jetlag ($MS_{\text{free days}} - MS_{\text{school days}}$). The adolescents were categorized into groups based on the US National Sleep Foundation (NSF) recommendations for sleep duration: <7 h (not recommended), 7–8 h (may be appropriate) or 8+ hours (recommended) [44]. Further, in order to visualize sleep duration in relation to circadian typology, the adolescents were grouped into 7 categories based on their sleep duration: <5 h, 5–6 h, 6–7 h, 7–8 h, 8–9 h, 9–10 h and 10+ hours.

2.4.3. Sleep-related behaviors

Respondents reported how many cups of caffeinated beverages they consumed each day, and how many days per week they used electronic media in bed after bedtime. Those who used electronic media in bed were further asked how it affected their sleep on a 5-point Likert scale, with response options "*I sleep much better*" = 1, "*I sleep better*" = 2, "*my sleep is not affected*" = 3, "*I sleep poorer*" = 4 and "*I sleep much poorer*" = 5.

2.4.4. Sleepiness and daytime functioning

Addressing sleepiness and daytime functioning, the respondents were asked to rate their level of agreement with the statements: *"If I rise early in the morning, I experience sleepiness during the early hours of the day"* and *"As a result of my sleep pattern, I have poor daytime functioning (eg mentally, physically, socially, on school)"*. The response alternatives (Likert scale) were "*strongly agree*" = 5, "*agree*" = 4, "*neither agree nor disagree*" = 3, "*disagree*" = 2 and "*strongly disagree*" = 1. The adolescents were also asked *"During the past three months, how many days per week have you been so sleepy/tired that it has affected you at school/work or in your private life?"* with response alternatives ranging from 0 days to 7 days.

2.4.5. Sleep beliefs and sleep satisfaction

In order to address beliefs about sleep need, the adolescents were asked the question *"How much sleep do you believe adolescents aged 16–19 years need?"* Responses were provided on a drop-down menu with 30-min intervals. We further calculated school day sleep deficit, operationalized as the difference between the adolescent's presumed sleep need and their actual school day sleep duration as reported on the MCTQ. Addressing sleep satisfaction, the adolescents were asked if they felt they obtained enough sleep on school days and on free days, respectively. Responses were provided on a 5-point Likert scale with response options "*far too little*" = 1, "*too little*" = 2, "*adequate*" = 3, "*too much*" = 4 and "*far too much*" = 5. In order to address the adolescents' perceived ability to change their sleep patterns, they were asked to rate their level of agreement with the following statement "*It would be easy for me to go to bed earlier, fall asleep earlier and rise earlier than I normally do on school days*". The response alternatives (Likert scale) were "*strongly agree*" = 5, "*agree*" = 4, "*neither agree nor disagree*" = 3, "*disagree*" = 2 and "*strongly disagree*" = 1.

2.5. Statistics

IBM SPSS Statistics 25 was used for statistical analyses. One-way ANOVAs were conducted to compare sleep parameters between the respective circadian types, using a Bonferroni corrected alpha level of 0.003 (0.05/20 analyses). In cases of significant overall results, Tukey HSD post-hoc tests for pairwise comparisons were performed. Chi-square analyses (3 × 3 cells) were performed to compare proportions of the circadian types obtaining <7 h, 7–8 h and 8+ hours of sleep, respectively. Chi-square analyses (3 × 3 cells) were also performed for the Likert scale items (response alternatives were collapsed into three groups, eg agree/totally agree, neither agree nor disagree, disagree/totally disagree). In cases of significant overall results, cells with larger/lower than expected frequencies were identified by post-hoc tests of adjusted residuals, using a Bonferroni corrected alpha level of 0.006 (0.05/3 × 3 cells).

3. Results

3.1. Circadian typology

In total, 39.9% of the respondents were categorized as evening types whereas 52.3% were categorized as intermediate types and only 7.8% were categorized as morning types. The age- and sex-specific distribution of circadian typology is displayed in Table 1. There were no age differences in circadian typology, but an overall sex difference indicating that girls more often were intermediate types.

3.2. Sleep

As expected, evening types had later sleep timing, more social jetlag and shorter school day sleep duration than morning types, with intermediate types displaying a sleep pattern between these two extremes (Table 2). Surprisingly, none of the circadian types had a mean sleep duration longer than 8 h on schooldays, and only morning types had a mean school day sleep duration >7 h (7:19 h, which was nearly one hour more than evening types who slept 6:20 h, $p < 0.001$ Tukey HSD) (Table 2). Amongst evening types, 61.9% obtained less than 7 h of sleep (not recommended, according to NSF) [44] compared to 42.6% of the intermediate and 29.6% of the morning types, and only 8.4% of the evening types obtained 8+ hours of sleep (recommended, according to NSF) [44], compared to 18.0% of the intermediate and 29.3% of the morning types (Table 3). Mean sleep duration was longer on free days, 8+ hours in all circadian types, and longest in evening types (8:51 h) (Table 2). The distribution of sleep duration in relation to circadian typology on schooldays and free days, respectively, is illustrated in Fig. 1.

Shuteye and sleep onset latencies differed between the circadian types, both on schooldays and on free days, with evening types taking the longest and morning types the shortest to fall asleep. Combined SEL and SOL was about half an hour longer in evening types than in morning types, both on schooldays (89 min vs. 54 min, $p < 0.001$ Tukey HSD) and on free days (71 min vs. 41 min, $p < 0.001$ Tukey HSD) (Table 2).

3.3. Sleep-related behaviors

Evening types reported using electronic media in bed more often, and morning types more seldom, than intermediate types (Table 2). Among evening types, 80.1% used electronic media in bed every night, compared to 72.0% among intermediate types and 52.4% among morning types (Chi-square = 107.79, $p < 0.001$). Among those who reported using electronic media in bed, most perceived it to have no effect on their sleep, with no differences between the circadian types (Table 3). The mean consumption of caffeinated beverages was highest in evening types (Table 2). A total of 72.6% of the evening types reported drinking caffeinated beverages, compared to 58.1% of the intermediate types and 44.6% of the morning types (Chi-square = 126.96, $p < 0.001$).

Table 1
Age and sex specific distribution of circadian typology (n = 3920).

Total	Circadian typology			Chi-square
	Morning	Intermediate	Evening	p
Total	307 (7.8%)	2050 (52.3%)	1563 (39.9%)	
Sex				
Female	161 (7.6%)	1156 (54.2%)↑	814 (38.2%)	χ^2 (2) = 7.14
Male	146 (8.2%)	894 (50.0%)↓	749 (41.9%)	p = 0.028
				$\varphi_c = 0.043$
Age				
16 years	185 (7.6%)	1291 (52.8%)	970 (39.7%)	χ^2 (2) = 0.97
17 years	122 (8.3%)	759 (51.5%)	593 (40.2%)	p = 0.617
				$\varphi_c = 0.016$

Post-hoc tests were performed to identify cells with larger/lower than expected frequencies (based on adjusted residuals), using a Bonferroni-corrected alpha level of 0.008 (alpha 0.05/2 × 3 cells).
↑Cells with larger than expected frequency, adjusted residual >2.6.
↓Cells with lower than expected frequency, adjusted residual < -2.6.

3.4. Sleepiness and daytime functioning

Evening types reported daytime sleepiness more often than the other circadian types (average 2.5 days per week compared to 1.7 days in intermediate and 1.1 days in morning types) (Table 2). Amongst evening types, 53.8% reported experiencing daytime sleepiness when rising early, compared to 35.4% amongst intermediate and 11.2% amongst morning types (Table 3). Moreover, 30.4% of the evening types experienced impaired daytime functioning as a consequence of their sleep pattern, compared to 19.5% of intermediate and 9.6% of morning types (Table 3).

3.5. Sleep beliefs and sleep satisfaction

When asked how much sleep they believed adolescents need, there were no differences between the circadian types (Table 2). Due to differences in school day sleep duration, the calculated school day sleep deficit was significantly larger in evening types (almost 2 h per day) than in the other two circadian types (Table 2). About 80% of the adolescents reported obtaining adequate sleep on free days, with no difference between the circadian types (Table 3). On schooldays, 63.8% of the evening types reported obtaining too little sleep, compared to 45.1% of the intermediate and 19.9% of the morning types (Table 3), respectively. A total of 42.0% of the evening types disagreed that it would be easy to go to bed, fall asleep and rise than they normally do on schooldays, compared to 32.3% of the intermediate and 23.1% of the morning types (Table 3).

4. Discussion

The results from this large sample of Norwegian 16–17 year-olds show a high prevalence of eveningness (almost 40%), and paint a disconcerting picture of sleep health in evening type adolescents. Despite late bedtimes, evening types take a long time to fall asleep and they often engage in electronic media usage in bed. Upon rising in time for school, they suffer from a clinically significant sleep loss (average 6:20 h sleep duration, which is far less than the 8+ hours recommended by the NSF) [44], and consequently, many evening types experience daytime sleepiness and impaired daytime functioning. Consumption of caffeinated beverages during the day is especially common among evening types, possibly in an attempt to overcome sleepiness. Finally, and quite disquietingly, evening types perceive it hard or impossible to change their sleep habits into earlier times.

In line with research showing a shift towards eveningness during adolescence [3–5,45], the prevalence of eveningness in the present study was high (almost 40%) and morningness low (less than 10%), compared to what is commonly reported in adult samples (about 20% for both morningness and eveningness) [3,46], thus lending support to hypothesis i). Interestingly, the prevalence of eveningness was also high compared to what has been reported in most comparable studies of adolescents and young adults [13,14,47,48]. Methodological disparities may account for some of these inconsistencies. Still, it is likely that sample-specific characteristics such as demography (eg age and sex), culture (eg social obligations) and/or geography (eg latitude of residence) have impact on the distribution of circadian typology [7,49]. Eveningness

Table 2

Sleep health in adolescents 16–17 years (n = 3920) in relation to circadian typology, presented in terms of means and SD. Results from one-way ANOVAs, with Bonferroni-corrections to account for multiple comparisons (corrected alpha level = 0.05/20 analyses = 0.003).

	Circadian typology			Post-hoc[a]	One-way ANOVA	Partial Eta Squared
	Morning (n = 307)	Intermediate (n = 2050)	Evening (n = 1563)		p-value	
Sleep on school days						
Bedtime (hr:min)	22:06 ± 55	22:24 ± 47	22:52 ± 62	M < I < E	<0.001	0.076
Rise time (hr:min)	06:34 ± 51	06:49 ± 35	07:02 ± 36	M < I < E	<0.001	0.049
Shuteye latency (minutes)	26 ± 36	40 ± 45	50 ± 66	M < I < E	<0.001	0.016
Sleep onset latency (minutes)	28 ± 49	29 ± 47	39 ± 53	M, I < E	<0.001	0.009
Wake after sleep onset (minutes)	8 ± 23	8 ± 22	9 ± 27		0.236	0.001
Early morning awakening (minutes)	8 ± 13	10 ± 14	13 ± 13	M < I < E	<0.001	0.010
Sleep duration (hr:min)	07:19 ± 75	06:57 ± 80	06:20 ± 92	M > I > E	<0.001	0.054
Sleep on free days						
Bedtime (hr:min)	23:35 ± 78	00:17 ± 71	01:05 ± 87	M < I < E	<0.001	0.115
Rise time (hr:min)	09:09 ± 86	10:42 ± 84	12:07 ± 92	M < I < E	<0.001	0.272
Shuteye latency (minutes)	21 ± 52	39 ± 48	43 ± 67	M < I, E	<0.001	0.010
Sleep onset latency (minutes)	20 ± 43	22 ± 45	28 ± 51	I < E	0.001	0.004
Wake after sleep onset (minutes)	6 ± 15	6 ± 20	7 ± 27		0.199	0.001
Early morning awakening (minutes)	34 ± 36	44 ± 39	53 ± 43	M < I < E	<0.001	0.020
Sleep duration (hr:min)	08:13 ± 90	08:35 ± 94	08:51 ± 104	M < I < E	<0.001	0.012
Sleep regularity						
Social jetlag (hr:min)	01:43 ± 73	02:32 ± 59	03:10 ± 65	M < I < E	<0.001	0.139
Sleep-related behaviors						
Electronic media usage in bed (days per week)	4.9 ± 2.7	6.0 ± 2.0	6.3 ± 1.7	M < I < E	<0.001	0.035
Consumption of caffeine (cups per day)	0.9 ± 1.8	1.0 ± 1.5	1.4 ± 1.8	M, I < E	<0.001	0.017
Sleep beliefs						
Sleep need (hr:min)	08:12 ± 97	08:10 ± 66	08:13 ± 77		0.469	<0.001
School day sleep deficit (hr:min)	00:53 ± 120	01:14 ± 97	01:53 ± 117	M, I < E	<0.001	0.039
Daytime sleepiness						
Days per week	1.1 ± 1.7	1.7 ± 1.8	2.5 ± 2.1	M < I < E	<0.001	0.052

[a] Tukey HSD post-hoc tests, significance level set to .003.

Table 3

Sleep health in adolescents (16–17 years) in relation to circadian typology, presented in terms of absolute and relative frequencies. Results from 3 × 3 Chi-square tests of independence.

	Circadian typology			Chi-square test of independence
	Morning	Intermediate	Evening	
School day sleep duration (n = 3920)				
< 7 h	91 (29.6%)↓	874 (42.6%)↓	968 (61.9%)↑	χ^2 (4) = 218.04
7–8 h	126 (41.0%)	806 (39.3%)↑	463 (29.6%)↓	p < 0.001
8+ hours	90 (29.3%)↑	370 (18.0%)↑	132 (8.4%)↓	φ_c = 0.17
How does electronic media use in bed affect your sleep? (n = 3651)				
I sleep better/much better	46 (18.1%)	286 (14.9%)↓	273 (18.4%)	χ^2 (4) = 8.50
My sleep is not affected	160 (63.0%)	1246 (65.0%)	936 (63.2%)	p = 0.075
I sleep poorer/much poorer	48 (18.9%)	385 (20.1%)	271 (18.3%)	φ_c = 0.03
Do you feel you obtain enough sleep on free days? (n = 3920)				
Too little/far too little	20 (6.5%)	125 (6.1%)	89 (5.7%)	χ^2 (4) = 10.38
Adequate	251 (81.8%)	1655 (80.7%)	1215 (77.7%)	p = 0.034
Too much/far too much	36 (11.7%)	270 (13.2%)	259 (16.6%)↑	φ_c = 0.04
Do you feel you obtain enough sleep on schooldays? (n = 3920)				
Too little/far too little	61 (19.9%)↓	925 (45.1%)↓	997 (63.8%)↑	χ^2 (4) = 279.16
Adequate	234 (76.2%)↑	1113 (54.3%)↑	559 (35.8%)↓	p < 0.001
Too much/far too much	12 (3.9%)↑	12 (0.6%)	7 (0.4%)	φ_c = 0.19
If I rise early in the morning I experience sleepiness during the early hours of the day (n = 3904)				
Agree/strongly agree	34 (11.2%)↓	723 (35.4%)↓	840 (53.8%)↑	χ^2 (4) = 320.80
Neither agree nor disagree	63 (20.8%)	548 (26.8%)	367 (23.5%)	p < 0.001
Disagree/strongly disagree	206 (68.0%)↑	770 (37.7%)↑	353 (22.6%)↓	φ = 0.20
As a result of my sleep pattern, I have poor daytime functioning (eg mentally, physically, socially, on school) (n = 3901)				
Agree/strongly agree	29 (9.6%)↓	398 (19.5%)↓	473 (30.4%)↑	χ^2 (4) = 171.45
Neither agree nor disagree	44 (14.5%)↓	555 (27.2%)	466 (29.9%)↑	p < 0.001
Disagree/strongly disagree	230 (75.9%)↑	1087 (53.3%)↑	619 (39.7%)↓	φ = 0.15
It would be easy for me to go to bed, fall asleep and rise earlier than I normally do on schooldays (n = 3888)				
Agree/strongly agree	109 (36.0%)↑	454 (22.3%)	289 (18.7%)↓	χ^2 (4) = 80.33
Neither agree nor disagree	124 (40.9%)	924 (45.4%)↑	609 (39.3%)↓	p < 0.001
Disagree/strongly disagree	70 (23.1%)↓	658 (32.3%)↓	651 (42.0%)↑	φ_c = 0.10

Post-hoc tests were performed to identify cells with larger/lower than expected frequencies (based on adjusted residuals), using a Bonferroni-corrected alpha level of 0.006 (alpha 0.05/3 × 3 cells).

↑Cells with larger than expected frequency, adjusted residual >2.8.

↓Cells with lower than expected frequency, adjusted residual < -2.8.

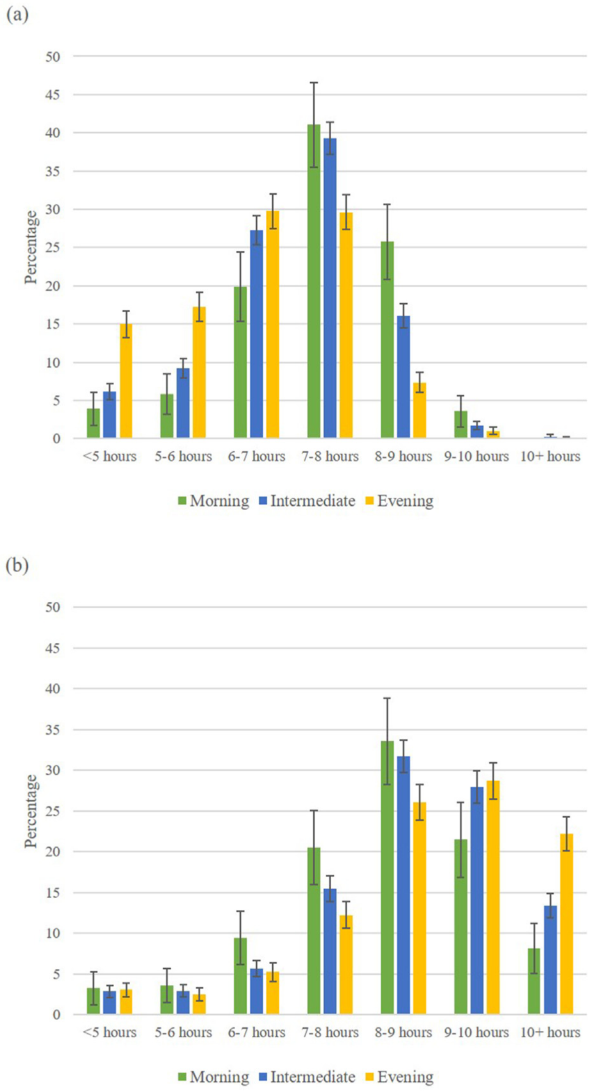

Fig. 1. Distribution of sleep duration in relation to circadian typology, on schooldays (a) and free days (b), respectively. Error bars represent 95% confidence intervals.

may be particularly common in the Scandinavian countries (Norway, Sweden, Denmark), which are situated at relatively high northern latitudes, combined with a culture allowing adolescents a large degree of freedom [50]. This notion is supported by a recent Swedish study reporting a similar distribution of circadian typology, skewed towards eveningness (32.5% evening types vs. 11.7% morning types) in young adults (16–26 years) [15]. Although the prevalence of eveningness in the Swedish study is somewhat lower than in the present, this is only to be expected considering the notion that eveningness seems to peak at the end of puberty [5,51]. In order to address the impact of sample characteristics (eg age and sex) and external factors (eg culture and geography) on circadian typology, future studies should be performed in different populations, at different geographical locations, using similar methodology.

Eveningness appeared to comprise a considerable sleep health problem in our sample. Consistent with previous studies [4,52], and in agreement with hypothesis ii), the evening types had later sleep timing, more social jetlag, and shorter school day sleep duration than the other circadian types. In fact, the proportion of adolescents that obtained 8+ hours of sleep on schooldays was more than 3-fold higher in morning types and more than 2-fold higher in intermediate types than in evening types. The average evening type reported sleeping only 6:20 h on school nights – thus obtaining almost 2 h less sleep than what the adolescents themselves believed to be the adolescent sleep need (averaged to 8:13 h), and 3 h less than what has been found necessary for 15–17 year olds to maintain optimal sustained attention performance, using a dose–response model [53].

Despite later bedtimes, evening types took about half an hour longer to fall asleep (combined SEL and SOL) than morning types. In accordance with this finding, the evening types also reported more behaviors that may be associated with late sleep timing, supporting hypothesis iii). In the present study, evening types used electronic media in bed more often than the other circadian types, and 8 out of every 10 evening types reported using electronic media in bed every night. Our findings are in agreement with previous findings that evening types may be prone to behaviors associated with late sleep timing [3], such as electronic media usage. Recent studies indicate that electronic media usage in bed may be an epiphenomenon of long sleep latency rather than its cause [19]. In order to accommodate social expectations, evening types may go to bed early in relation to their biological timing for sleep and before they feel sleepy [17]. Through a vicious circle, activities before bedtime (as well as in bed) may in turn promote late sleep onset, both by direct displacement of sleep time (late bedtimes and long shuteye latency) and by affecting sleep onset latency (eg light-induced alertness, emotional and cognitive arousal, worry/rumination, fear or missing out, messages on social media etc.) [20,21].

Evening types also consumed more caffeinated beverages than the other circadian types, possibly as a compensation for daytime sleepiness. In support of hypothesis iv), evening types reported more daytime sleepiness than the other circadian types. More than 50% of evening types experienced sleepiness during the early hours of the day and more than 30% reported having poor daytime functioning as a result of their sleep pattern. Further, in accordance with hypothesis v), more than 60% of the evening types reported not obtaining enough sleep on schooldays. There is substantial evidence that adolescents worldwide obtain far less sleep than they need on schooldays [34,42,54,55]. Aiming to improve sleep in adolescents, several researchers have investigated the effect of sleep education programs in youths, with or without motivational components, but with limited success rates [56–59]. Recognizing eveningness as a major barrier for advancing sleep schedules, some researchers have also included chronobiological elements in adolescent sleep programs [57,59]. Still, eveningness may reflect not only circadian dispositions, but also behaviors that exacerbate delayed sleep timing as well as traits that prevent adherence to behavioral changes necessary to advance sleep timing (eg low score on conscientiousness) [12]. Thus, in order to better tailor sleep education programs, future research should address the contribution of biological (circadian rhythm), educational (knowledge), environmental (parental involvement) and motivational (willingness) barriers for sleep-behavioral changes in youths, and their relation to circadian typology. This notion is underlined by results from the present study, that evening types perceive it more difficult to change their sleep pattern towards earlier bed- and rise times than the other circadian types.

As a final remark, it is worth noticing that poor and curtailed sleep were not limited to the evening types. In fact, none of the circadian types had a mean sleep duration of the recommended 8 h on schooldays [44], and only morning types had a mean school day sleep duration >7 h. Moreover, also the intermediate and morning types had substantial levels of social jetlag (2:32 h in intermediate and 1:44 h in morning types, which is partially in contrast to studies among adults, indicating shortest social jetlag in intermediate types [4]). The fact that the majority of adolescents in the present study obtained 8+ hours of sleep on free days, irrespective of CT, indicates that most adolescents have the biological ability to obtain adequate amounts of sleep when given the opportunity to sleep *ad libitum*. Accordingly, one intuitive intervention to promote sleep in adolescents is to delay school start times, as it will provide adolescents with an opportunity to obtain more sleep at a time that matches their circadian disposition [60,61].

4.1. Strengths and limitations

The strengths of the present study include a relatively large, population-based sample and the use of validated questionnaires to address sleep (MCTQ) and circadian typology (rMEQ). MCTQ measures sleep on schooldays and free days separately, which is of crucial importance when investigating adolescent sleep. rMEQ is a commonly used morningness-eveningness questionnaire, and has previously been shown to have good reliability [12,15,47,62]. In the present study, the reliability of the rMEQ measured by Cronbachs's alpha was somewhat low compared to previous studies [15,47,62]. It is, however, similar to what was reported in a previous Norwegian study, suggesting that the low internal consistency may be related to the Norwegian translation of the scale [63]. Still, the Norwegian version of rMEQ had adequate convergent validity against other measures of morningess and concurrent validity against actigraphic data [63]. The study was conducted within a narrow range of time (April through June), thus minimizing the impact of seasonal variations in sleep and circadian typology. It cannot be ruled out that circadian typology may change across seasons, hence this topic should be explored by future studies. With respect to instruments, the study did not include a validated sleepiness scale, which represents a limitation of the present study. Furthermore, the study did not include a measure for pubertal staging, thus it was not possible to address possible interactions between circadian typology, sleep and pubertal development. In terms of study design, the cross-sectional design represents a limitation when interpreting the findings, as it does not allow for conclusions regarding directionality and cause-and-effect. All results are based on self-report and were not corroborated by objective measurements, which are rarely feasible to include in large, population-based studies. Hence, the findings may have been influenced by the common method bias [64]. Another limitation concerns the modest response rate of 42%. There were, however, large differences between the schools in terms of response rate, ranging from 0% to 100%, which suggests systematic differences in management at the school level in terms of invitation, information and facilitation rather than selection bias at the individual level. Still, a response rate of 42% is considered acceptable for this kind of research [65]. Furthermore, it should be noted that only high school students were invited to participate. Hence, findings may not be generalizable to adolescents not attending school [66].

4.2. Conclusions

In conclusion, the present study provides novel information about the distribution of circadian typology in adolescents and its relation to sleep. The results indicate that eveningness represents a public sleep health challenge for older adolescents, and highlights the need to take circadian typology into account when addressing adolescent sleep health.

Credit author statement

Dr Saxvig administered the project, conceptualized and designed the study, collected data, carried out the analyses, interpreted the results, drafted the initial manuscript and revised the manuscript.

Evanger collected data, interpreted the results and revised the manuscript.

Dr Pallesen conceptualized and designed the study, collected data, interpreted the results and revised the manuscript.

Dr Sivertsen and Dr Hysing conceptualized and designed the study, interpreted the results and revised the manuscript.

Dr Gradisar interpreted the results and revised the manuscript.

Dr Bjorvatn conceptualized and designed the study, interpreted the results and revised the manuscript.

All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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Conflict 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.2021.04.020.

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