



Original Article

Excessive daytime sleepiness among children and adolescents: prevalence, correlates, and pubertal effects



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ABSTRACT

Objectives: To examine the prevalence and correlates of excessive daytime sleepiness (EDS) among Hong Kong children and adolescents. We investigated the potential roles of sex and puberty in modulating the occurrence of EDS.

Methods: A total of 10,086 students (male, 48.1%) aged 6–18 (mean \pm SD: 12.3 \pm 3.2) years old participated in this cross-sectional survey. EDS was defined by a total score $>$ 18 on the Pediatric Daytime Sleepiness Scale. Sociodemographic characteristics, time in bed, chronotypes, sleep problems, emotional and behavioral difficulties, mental health, and pubertal stages were assessed.

Results: The overall prevalence of EDS was 29.2%, and increased from 19.8% at Tanner stage 1 (pre-puberty) to 47.2% at Tanner stage 5 (post-puberty). Female predominance emerged at Tanner stage 3 (mid-puberty). EDS was significantly associated with short weekday time in bed, both long and short weekend time in bed, eveningness chronotype, insomnia symptoms, and sleep-disordered breathing symptoms. Females were more likely to have short weekday time in bed and eveningness chronotype than males. Children and young adolescents at pre and mid-puberty were protected against EDS by morningness chronotype. EDS was independently associated with daytime napping, alcohol and energy beverage consumption, emotional and behavioral difficulties, as well as poor mental health even after adjusting for potential confounding factors.

Conclusions: EDS is prevalent among children and adolescents with the emergence of female preponderance at mid-puberty and independent association with pervasive adverse emotional and behavioral problems. The mechanisms underlying the modulation effects of sex and puberty on EDS merit further investigation.

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1. Introduction

Excessive daytime sleepiness (EDS) is a global major health concern affecting up to 40% of children and adolescents [1,2]. As EDS significantly increases with age during adolescence [1], it suggests that puberty may play a critical role in the development of EDS. Puberty is a critical period for a transition from childhood to

adulthood, associated with changes in sleep structure [3], delayed circadian phase [4], and increased sleep disturbances including insomnia [5]. Conversely, the etiology of EDS is likely to be complex and interrelated [6,7], as it may be associated with insufficient sleep [8–10], eveningness chronotype [4], sleep disturbances [11], and lifestyle factors (eg, electronics use) [12]. Nonetheless, the detailed interactions of puberty with these multiple factors, especially on the occurrence of EDS during adolescence remain unclear.

There has been a consistent female predominance of sleep problems and EDS among adolescent and adult population, but not in children [13–16]. In this regard, it was reasonable to hypothesize the emergence of female predominance of EDS at some time point during pubertal maturation, albeit there was no current supporting

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data. However, EDS in the young population is tightly associated with mood dysregulation, behavioral problems, and substance misuse [9,17–19]. As insomnia and eveningness chronotype are also found to be associated with mood and behavioral problems [5,18,20], it remains unclear whether the association of EDS with these adverse health consequences is independent of those of sleep and chronotype effects.

Thus, we hypothesized that the prevalence of EDS might increase along with pubertal development during which sex difference in EDS emerges. We aimed (1) to explore the prevalence of EDS across pubertal stages and determine the time point at which sex differences emerge; (2) to investigate the correlates of EDS in terms of demography, time in bed, sleep problems, chronotype, daytime activities, lifestyle factors, and mental health consequences; and (3) to investigate the potential interactive effects of sex and puberty with time in bed and chronotype on the occurrence of EDS.

2. Methods

2.1. Study design, procedure, and sample recruitment

The present study was part of a large-scale sleep education program (Healthy Sleep, Healthy School Life) which involved students from 31 primary and secondary schools in Hong Kong [21,22]. Ethical approval was obtained from the Joint CUHK-NTEC clinical research ethics committee (reference no: CRE-2011.249-T). The data collected in this study were from a cross-sectional survey [5,21]. Baseline questionnaires, a consent form for both parent(s)/caregiver(s), and individual assent were packed into envelopes and delivered to all eligible students in their schools. The questionnaires for primary school students were completed by their parents whereas the questionnaires for secondary school students were completed by the students themselves. Students were asked to return the signed consents and assents and completed questionnaires within one week.

2.2. Measurements

2.2.1. Socio-demographics, lifestyle factors, and daytime activities

All participants reported their demographic characteristics including date of birth, sex, monthly family income (<HK\$15,000, ≥ HK\$15,000; HK\$7.8 = US\$1), and lifestyle factors. Lifestyle factors included the frequency of tea drinking, coffee drinking, alcohol drinking, and energy beverage consumption over the past month. The frequency of lifestyle factors was recorded as follows: (1) 'no'; (2) 'seldom'; (3) 'sometimes'; and (4) 'often (three times or more/week)'. Participants were also asked about their frequency of taking a daytime nap (None, 1–2 days/week, three times or more/week).

The average time spent on the following daytime activities was assessed: homework, watching TV, and playing electronic games.

2.2.2. Time in bed and EDS

Bedtime and wakeup time of both weekdays and weekend days were collected by self-report questionnaire. Time in bed was defined as the period from bedtime to wake-up time [21]. EDS was measured by the Pediatric Daytime Sleepiness Scale (PDSS) which consists of eight items focusing on the level of sleepiness in different situations [23]. The questions were presented in a Likert-scale format (never, seldom, sometimes, frequently, and always). The Chinese version of PDSS has been validated among children and adolescents aged 6–18 years with acceptable test-retest reliability (0.78) and internal consistency (Cronbach's alpha = 0.61–0.81) [24]. A cut-off >18 on the total score of PDSS was used to identify individuals with EDS [24].

2.2.3. Pubertal status

Pubertal status was assessed by Tanner Staging using a self-assessment questionnaire which was based on secondary sexual characteristics such as breast/genital development as well as pubic hair growth. The Tanner Staging classifies pubertal status into five stages which covers a range from pre-puberty to post-puberty. This validated scale has moderate to almost perfect agreement between self-reported and rater-rated assessment of pubertal stages in Chinese adolescents [25]. Pre-puberty, mid-puberty, and post-puberty were defined as Tanner stage 1, Tanner stage 2 and 3, and Tanner stages 4 and 5, respectively [26].

2.2.4. Chronotype

The Children's Chronotype Questionnaire (CCTQ) was used to assess the primary school children's chronotype, which is a parent-report, 27-item questionnaire measuring chronotype in 4–11-year-old children [27]. Chronotype was categorized as morningness type (score ≤ 23), intermediate type (score 24–32), and eveningness type (score ≥ 33) [27]. Some of the items were measured on a 5-point Likert scale whereas other items were measured on a 5-point time series scale. The reduced validated Chinese version of the Morningness-Eveningness Questionnaire (rMEQ) was employed to assess the chronotype of secondary school adolescents [28,29]. rMEQ is a self-report, 5-item questionnaire with the following cut-offs: morningness type (score ≥ 18), intermediate type (score 12–17), and eveningness type (score ≤ 11) [28].

2.2.5. Sleep problems

Insomnia symptoms were assessed by the following questions: 'During the past month, how often have you had (1) difficulty falling asleep? (2) sudden awakening from sleep and difficulty returning to sleep? (3) early morning awakening and being unable to return to sleep?'. Individuals with any insomnia symptoms of least three times/week were considered abnormal as proposed by the Diagnostic and Statistical Manual of Mental Disorders, fifth edition (DSM-5).

The symptoms of sleep-disordered breathing (SDB) were measured by the following questions: 'During the past month, how often have you had (1) snoring during sleep?; (2) breath holding for a few seconds?; and (3) or nocturnal breathing difficulty?'. Participants were asked to rate the frequency of their symptoms of sleep disorders on a 5-point Likert scale ('1' = never, '2' = less than once per month, '3' = once or twice per month, '4' = once or twice per week, '5' = at least three times per week). Individuals with any of these symptoms at least three times/week were considered having probable SDB symptoms.

2.2.6. Emotional and behavioral difficulties as well as mental health

The Strengths and Difficulties Questionnaire (SDQ) is a locally validated brief screening questionnaire designed to assess emotional and behavioral problems in the following five aspects: peer relationships, hyperactivity/inattention, prosocial behaviors, emotional and behavioral problems [30]. Each item can be marked as 'not true,' 'somewhat true,' and 'certainly true.' The cut-off for identifying abnormal cases based on SDQ total difficulties score was ≥16 for self-reported data (secondary school) and ≥14 for parent-reported data (primary school), respectively [31].

The Chinese version of the General Health Questionnaire (GHQ-12) was employed to evaluate the mental health status of the adolescents. All items were measured on a 4-point Likert scale. A GHQ-12 score ≥ four was considered as having poor mental health [32]. The GHQ-12 was only employed among secondary school adolescents (self-reported), not primary school children.

2.3. Statistical analyses

Descriptive statistics were presented as percentages for discrete variables and means \pm standard deviation for continuous variables. Independent sample t-test and chi-square test were performed where appropriate. We classify three categories of time in bed ('short,' 'normal,' and 'long') by the age-specified 'mean \pm standard deviation' of time in bed as cut-offs in these participants. For example, the cut-offs of time in bed (hour) during weekday were 8.4 and 9.9 for participants aged six years old, and 5.8 and 8.2 for participants aged 18 years old. The cut-offs of time in bed (hour) during the weekend were 9.4 and 11.2 for participants aged six years old, and 8.4 and 11.6 for participants aged 18 years old. The association of EDS with socio-demographic characteristics, sleep- and circadian-related factors, and daily activities were analyzed with logistic regression models adjusting for age with EDS as the dependent variable. Furthermore, the interactions between sex and time in bed (weekday, weekend) as well as chronotype, and the interactions between puberty and time in bed (weekday, weekend), as well as chronotype, were tested using logistic regression models while adjusting for potential confounders (age or gender). To investigate if EDS was independently associated with lifestyle factors, emotional and behavioral difficulties, as well as physical and mental health, logistic regression models were employed with EDS as an independent variable, adjusting for age, sex, time in bed, chronotype, insomnia symptoms, and SDB related symptoms. Odds ratio (OR) and 95% confidence interval (CI) were calculated with the logistic regression models. A p-value of less than 0.05 was considered significant. All statistical analyses were performed using SPSS version 22.0 (Armonk, NY: IBM Corp.).

3. Results

3.1. The prevalence of EDS across pubertal stages and its demographic and biological correlates

A total of 19,341 students were eligible to participate in this study, of which 10,671 (55.2%) returned the questionnaires between December 2011 and March 2012. Among the respondents, a total of 10,086 (94.5%) children and adolescents (male, 48.1%) aged from 6 to 18 years old (mean age: 12.3 ± 3.2 years) had a valid PDSS score, and 7373 (69.1%) had both a valid PDSS and Tanner pubertal stage assessment.

EDS was found in 29.2% of the total sample, with a significant gender difference (24.4% in males vs. 33.6% in females, $p < 0.001$). The prevalence of EDS increased from 19.8% at Tanner stage 1 (pre-puberty) to 47.2% at Tanner stage 5 (post-puberty) (linear by linear association, $p < 0.001$, Fig. 1). Fig. 1 shows the prevalence of EDS across different pubertal stages in both males and females. Female predominance of EDS emerged at Tanner stage 3 (mid-puberty) (female vs. males: 32.7% vs. 25.6%, $p = 0.004$). There was an interaction of sex with pubertal staging ($p = 0.006$), which suggested that females were more vulnerable to EDS than males during pubertal maturation.

Table 1 shows the differences in socio-demographic and sleep-related characteristics, and pubertal status between participants with and without EDS. Participants with EDS were older (13.3 ± 3.0 vs. 11.8 ± 3.2 years old, $p < 0.001$), more were females (59.8% vs. 48.6%, $p < 0.001$), and were sleeping shorter during weekday (7.5 ± 1.2 vs. 8.3 ± 1.1 h, $p < 0.001$), when compared to participants without EDS. No differences in monthly family income and weekend time in bed were found between participants with and without EDS.

3.2. The association of EDS with time in bed, chronotype, sleep problems, and daytime activities

Table 2 shows the correlates of EDS regarding time in bed, chronotype, sleep problems, and daytime activities. With regard to normal weekday time in bed, short weekday time in bed increased the risk of EDS (OR, 2.22; 95%CI, 1.96–2.50; $p < 0.001$) while long weekday time in bed protected participants against EDS (OR, 0.52; 95%CI, 0.45–0.61; $p < 0.001$). A U-shaped association of weekend time in bed with EDS was found: both short (OR, 1.19; 95%CI, 1.05–1.35; $p < 0.01$) and long (OR, 1.40; 95%CI, 1.23–1.59; $p < 0.001$) weekend time in bed were associated with higher risk of EDS. In addition, eveningness was the strongest factor associated with EDS (OR, 12.38; 95%CI, 9.31–16.44, $p < 0.001$), followed by insomnia symptoms (OR, 2.79; 95%CI, 2.38–3.27, $p < 0.001$), SDB related symptoms (OR, 2.18; 95%CI, 1.88–2.54, $p < 0.001$), and playing electronic games more than 1 h/day (OR, 1.56; 95%CI, 1.41–1.74, $p < 0.001$). These associations were similar between males and females.

3.3. The effects of sex and puberty on EDS

Fig. 2 shows the association of EDS with time in bed and chronotype. Fig. 2A–C demonstrate that females were more likely to report EDS than males. Compared to long weekday time in bed, the prevalence of EDS was 2.37 times higher in males with a short time in bed while nearly three times higher in females with a short time in bed (sex \times weekday time in bed interaction, $p < 0.001$). Furthermore, females were more likely to have eveningness chronotype than males (Fig. 2C). Compared to those with morningness, the prevalence of EDS was 5.53 times higher in males with eveningness while 6.08 times higher in females with eveningness (sex \times chronotype interaction, $p = 0.04$). Note that Fig. 2B shows a U-shaped curve of the prevalence of EDS in relation to weekend time in bed. In particular, both short and long time in bed during weekends were associated with a higher prevalence of EDS in both males and females.

Fig. 2D–F suggest that participants at post-puberty were more likely to report EDS when compared with participants at mid- or pre-puberty. Fig. 2F shows a significant interaction of puberty with chronotype (puberty \times chronotype interaction, $p < 0.001$). It suggests that participants at the pre- and mid-pubertal stage were more likely to be protected by morningness chronotype than participants at post-pubertal stages.

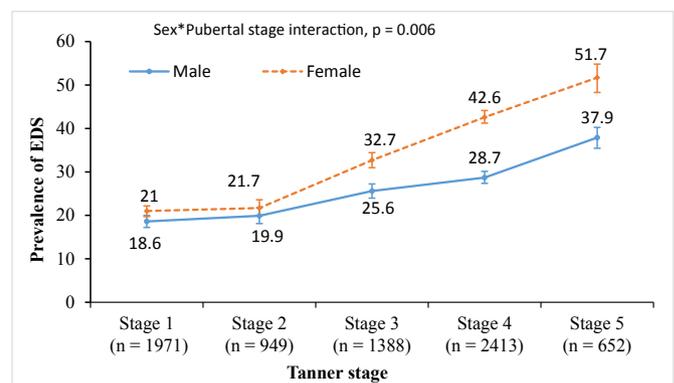


Fig. 1. The prevalence of EDS across pubertal stages among male and female. Error bars represent 95% confidence interval. If confidence intervals do not overlap between male and female, then the difference between the estimates is statistically significant. The interaction of sex with pubertal stage was calculated with logistic regression after adjusting for age and main effect of sex and puberty.

Table 1
Demographic and pubertal characteristics as well as sleep duration between participants with and without EDS.

	Total sample (n = 10,086)		P value
	No EDS (n = 7143)	EDS (n = 2943)	
Age, years, mean ± SD	11.8 ± 3.2	13.3 ± 3.0	<0.001
Sex, female, %	48.6	59.8	<0.001
Family income, < 15,000 HKD/month, %	35.0	34.5	0.61
Pubertal status ^a			<0.001
Tanner stage 1, % (n = 1971)	80.2	19.8	
Tanner stage 2, % (n = 949)	79.2	20.8	
Tanner stage 3, % (n = 1388)	70.3	29.7	
Tanner stage 4, % (n = 2413)	63.2	36.8	
Tanner stage 5, % (n = 652)	52.8	47.2	
Time in bed (weekday), hours, mean ± SD	8.3 ± 1.1	7.5 ± 1.2	<0.001
Time in bed (weekend), hours, mean ± SD	10.1 ± 1.2	10.0 ± 1.4	0.18

EDS, excessive daytime sleepiness; SD, standard deviation.

^a n = 7373.

Table 2
The associations of EDS with time in bed, chronotype, sleep problems, and daytime activities.

	Total sample (n = 10,086)				Male (n = 4851)				Female (n = 5235)			
	n	EDS (%)	OR ^a	95% CI	n	EDS (%)	OR ^b	95% CI	n	EDS (%)	OR ^b	95% CI
Time in bed (weekday) ^c												
Short	1389	47.1	2.22	1.96–2.50***	563	36.6	1.82	1.50–2.20***	826	54.2	2.52	2.15–2.95***
Normal	7321	28.1	Reference		3506	24.4	Reference		3815	31.5	Reference	
Long	1325	16.7	0.52	0.45–0.61***	752	15.4	0.55	0.45–0.68***	573	18.3	0.50	0.40–0.63***
Time in bed (weekend) ^c												
Short	1404	31.3	1.19	1.05–1.35**	775	26.5	1.17	0.98–1.40	629	37.2	1.21	1.01–1.45*
Normal	7230	27.5	Reference		3450	22.9	Reference		3780	31.7	Reference	
Long	1376	35.8	1.40	1.23–1.59***	585	30.1	1.40	1.15–1.70***	791	39.9	1.41	1.20–1.66***
Chronotype												
Morningness	718	8.1	Reference		372	7.8	Reference		346	8.4	Reference	
Intermediate	5825	23.6	3.45	2.61–4.56***	2764	18.8	2.77	1.87–4.10***	3061	27.9	4.15	2.80–6.16***
Eveningness	2592	47.5	12.38	9.31–16.44***	1161	43.1	10.52	7.05–15.71***	1431	51.1	14.21	9.50–21.26***
Insomnia symptoms												
<3 times/week	9253	27.4	Reference		4465	22.9	Reference		4788	31.7	Reference	
≥3 times/week	705	53.5	2.79	2.38–3.27***	317	46.4	2.76	2.19–3.50***	388	59.3	2.80	2.25–3.48***
Sleep-disordered breathing-related symptoms												
<3 times/week	9091	28.0	Reference		4256	22.5	Reference		4835	32.8	Reference	
≥3 times/week	832	42.4	2.18	1.88–2.54***	504	41.3	2.47	2.04–3.00***	328	44.2	1.84	1.45–2.33***
Time spent on daytime activities												
Homework, < 1 h/day	5171	29.5	Reference		2738	25.5	Reference		2433	34.1	Reference	
Homework, ≥ 1 h/day	4915	28.8	1.06	0.97–1.16	2113	23.0	1.01	0.88–1.13	2802	33.2	1.06	0.94–1.20
Watching TV, < 1 h/day	6498	27.8	Reference		3183	23.3	Reference		3315	32.2	Reference	
Watching TV, ≥ 1 h/day	3588	31.6	1.07	0.98–1.17	1668	26.4	1.11	0.97–1.27	1920	36.1	1.04	0.92–1.17
Playing electronic game, < 1 h/day	7800	25.5	Reference		3706	21.1	Reference		4094	29.4	Reference	
Playing electronic game, ≥ 1 h/day	2286	41.9	1.56	1.41–1.74***	1145	35.0	1.68	1.44–1.96***	1141	48.7	1.48	1.28–1.71***

OR, odds ratio; CI, confidence interval.

*p < 0.05; **p < 0.01; ***p < 0.001.

^a Odds ratio was calculated with logistic regression adjusted for age, sex.

^b Odds ratio was calculated with logistic regression adjusted for age.

^c Sleep duration was categorized with mean ± standard deviation of sleep duration as the cut-offs in each age group.

3.4. The correlates of EDS regarding lifestyle factors, emotional and behavioral difficulties, and physical and mental health

Table 3 shows the association of EDS with lifestyle factors, emotional and behavioral difficulties, and physical and mental health. Among the total sample, even after adjusting for age, sex, time in bed, chronotype, insomnia symptoms, and SDB related symptoms, EDS was still independently associated with daytime napping (OR, 2.62; 95%CI, 2.19–3.14; p < 0.001), coffee drinking (OR, 1.46; 95%CI, 1.05–2.03; p < 0.05), alcohol drinking (OR, 1.63; 95%CI, 1.39–1.92; p < 0.001), energy beverage consumption (OR, 1.74; 95%CI, 1.13–2.68; p < 0.05), SDQ total difficulties (OR, 3.30; 95%CI, 2.96–3.68; p < 0.001), and poor mental health (OR, 2.67; 95%CI, 2.26–3.14; p < 0.001). This pattern of associations was similarly observed in both males and females.

4. Discussions

The present large-scale community-based study revealed that EDS was prevalent among children and adolescents in Hong Kong. The prevalence of EDS progressively increased with pubertal maturation, with the emergence of the female preponderance of EDS at mid-puberty. EDS was significantly associated with short weekday time in bed, short and long weekend time in bed, eveningness chronotype, insomnia symptoms, and SDB related symptoms. Furthermore, there was an interaction between puberty and chronotype on the prevalence of EDS. Females were more likely to have a short time in bed and eveningness chronotype than males, while those children and adolescents at pre- and mid-puberty were more likely to be protected against EDS by morningness chronotype. Moreover, even after adjusting for other

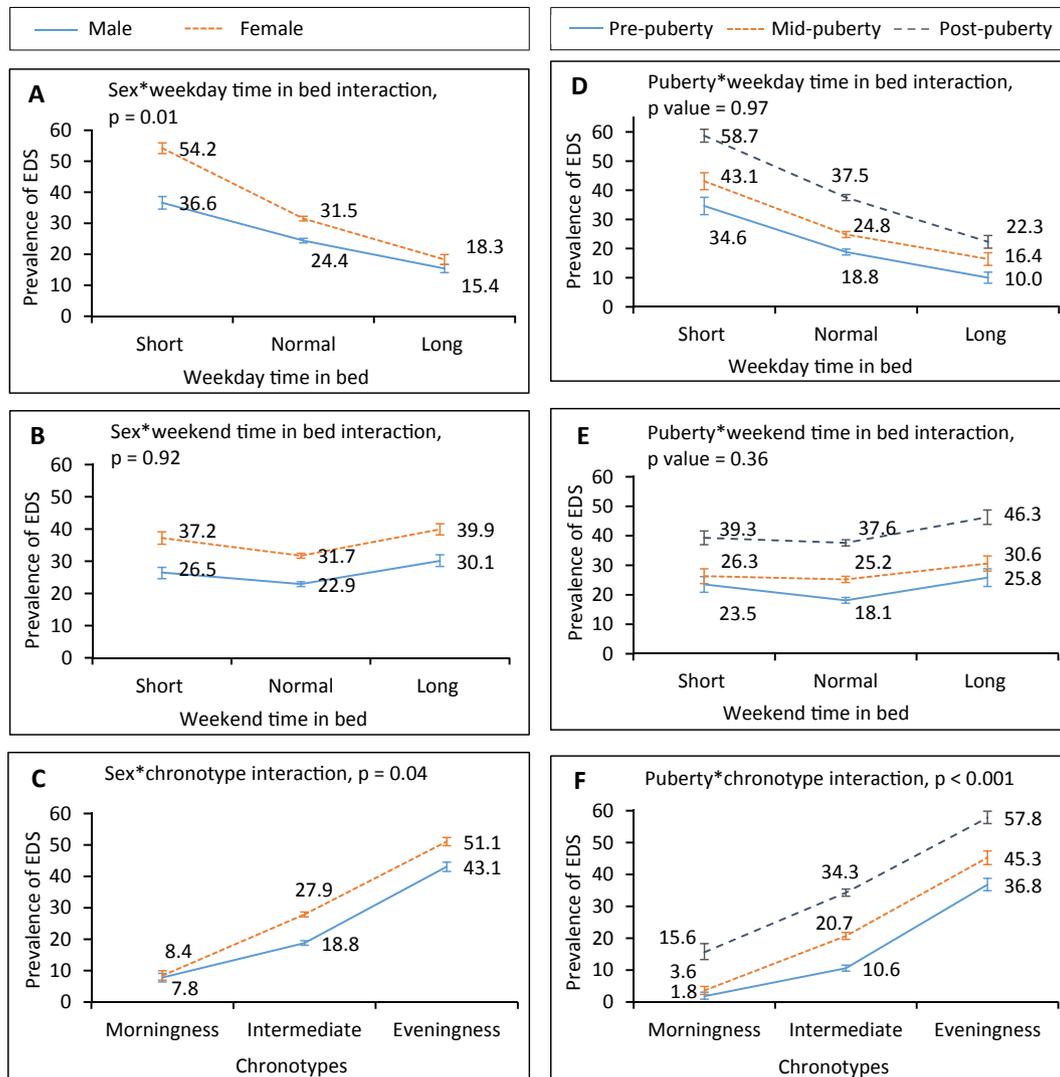


Fig. 2. The effects of sex and puberty on EDS across time in bed and chronotype. Error bars represent 95% confidence interval. If 95% confidence intervals do not overlap, then the difference between the estimates is statistically significant. Interactions were calculated with logistic regression model adjusted for age (2A, 2B, and 2C) and sex (2D, 2E, and 2F).

confounding variables, EDS was independently associated with daytime napping, alcohol and ‘energy’ beverage consumption, emotional and behavioral difficulties, as well as poor mental health.

The fact that a high prevalence of EDS was found among children and adolescents should alert health professionals, parents, and education authorities. The prevalence of EDS (29.2%) found in this study was comparable to the figures reported in other Asian countries such as Japan (36.2%) [33], and Taiwan (35.7%) [34], in addition to a previous local study (25.2%) [35]. It should be disclosed that the prevalence of EDS reached up to 47% among participants at Tanner stage 5, which was as high as to some clinical population such as adolescents with attention deficit hyperactivity disorder and internet addiction [36,37]. However, this high EDS prevalence at Tanner stage 5 was also comparable to other studies conducted in Hong Kong, Canada, and Australia [1,2,38]. Thus, these findings suggest that sleepiness among adolescents is a global issue, especially in developed countries and urban areas.

One major contributing factor to EDS is insufficient sleep [8–10]. Although we classified the time in bed into ‘short,’ ‘normal,’ and ‘long’ using mean \pm standard deviation of time in bed as cut-offs, more than half of the participants (Table S1) were not having adequate weekday sleep as according to the latest recommendation

[39]. Given that sleep is so important in maintaining good mental health among children and adolescents, EDS may serve as a potential marker for insufficient sleep and the occurrence of psychiatric problems [40]. However, we also found that EDS was associated with both long and short time in bed. This finding was similar to recent reports that both long and short sleep duration was associated with elevated levels of daily distress and mood symptoms [41,42]. These findings suggest that different mechanisms might underlie the relationship between sleep duration and the regulation of sleepiness and mood among children and adolescents. Although the mechanisms of a nonlinear association between EDS and sleep duration (time in bed) are not fully clear, several possible explanations need to be noted. Sleep compensation during weekends for sleep debt accumulated during weekdays might be one of the explanations for the U-shaped curve of the prevalence of EDS. To some extent, weekend sleep compensation might be beneficial for the sleep-deprived children and adolescent [43,44]. However, the reason for EDS being related to long weekend time in bed is intriguing. First, excessive sleep compensation during the weekend may predispose adolescents to develop a phenomenon known as ‘social jet-lag,’ resulting from circadian rhythm disruption [43]. In particular, adolescents with eveningness

Table 3
The associations of EDS with lifestyle factors, emotional and behavioral difficulties, and physical and mental health.

	Total sample (n = 10,086)				Male (n = 4851)				Female (n = 5235)			
	No EDS, n (%)	EDS, n (%)	OR	95% CI	No EDS, n (%)	EDS, n (%)	OR ^a	95% CI	No EDS, n (%)	EDS, n (%)	OR ^a	95% CI
Napping, ≥ 3 times/week	325 (4.6)	426 (14.6)	2.62	2.19–3.14***	175 (4.8)	184 (15.7)	2.90	2.23–3.77***	150 (4.4)	242 (13.8)	2.51	1.96–3.22***
Tea drinking, ≥ 3 times/week	399 (5.6)	279 (9.5)	1.18	0.98–1.43	216 (5.9)	94 (7.9)	1.05	0.78–1.42	183 (5.3)	185 (10.5)	1.30	1.01–1.66*
Coffee drinking, ≥ 3 times/week	103 (1.4)	96 (3.3)	1.46	1.05–2.03*	69 (1.9)	50 (4.2)	1.48	0.96–2.28	34 (1.0)	46 (2.6)	1.49	0.89–2.50
Alcohol drinking, ≥ 3 times/week	508 (7.1)	404 (13.7)	1.63	1.39–1.92***	336 (9.2)	219 (18.5)	1.65	1.34–2.06***	172 (4.9)	185 (10.5)	1.70	1.33–2.19***
'Energy' beverage drinking, ≥ 3 times/week	70 (1.0)	57 (1.9)	1.74	1.13–2.68*	51 (1.4)	31 (2.6)	1.53	0.88–2.68	19 (0.5)	26 (1.5)	2.22	1.09–4.51*
SDQ total difficulties	1570 (22.5)	1382 (48.1)	3.30	2.96–3.68***	889 (25.2)	594 (52.1)	3.08	2.62–3.62***	671 (19.6)	788 (45.5)	3.42	2.94–3.97***
SDQ emotional symptoms	1151 (16.5)	991 (34.5)	2.66	2.37–3.00***	521 (14.6)	339 (29.7)	2.44	2.02–2.94***	630 (18.4)	652 (37.6)	2.75	2.36–3.21***
SDQ peer relationship problems	2650 (38.0)	1068 (37.2)	1.18	1.06–1.31**	1593 (43.3)	520 (45.6)	1.11	0.95–1.30	1111 (32.5)	548 (31.7)	1.27	1.10–1.48***
SDQ conduct problems	1595 (22.9)	1119 (39.0)	2.48	2.22–2.78***	919 (25.8)	537 (47.1)	2.53	2.15–2.98***	676 (19.8)	582 (33.6)	2.47	2.11–2.90***
SDQ hyperactivity/inattention	1182 (16.9)	1145 (39.9)	3.54	3.15–3.98***	718 (20.2)	515 (45.1)	3.40	2.86–4.04***	464 (13.6)	630 (36.4)	3.57	3.03–4.20***
SDQ prosocial behavior	1969 (28.2)	938 (32.7)	1.35	1.21–1.51***	1218 (34.2)	472 (41.4)	1.38	1.18–1.62***	751 (21.9)	466 (26.9)	1.33	1.14–1.55***
GHQ ≥ 4 ^b	337 (11.1)	563 (27.6)	2.67	2.26–3.14***	163 (9.3)	185 (25.3)	3.16	2.42–4.14***	214 (13.1)	378 (28.9)	2.38	1.93–2.93***

Logistic regression models were performed to assess the association between various variables (dependent variables) and EDS (independent variable) adjusted for age, sex (^a except for sex), time in bed, chronotype, insomnia symptoms, and sleep-disordered breathing-related symptoms.

SDQ, Strengths and Difficulties Questionnaire; GHQ, General Health Questionnaire; OR, odds ratio; CI, confidence interval.

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

^b GHQ was just performed among adolescents in secondary school.

chronotype may be more vulnerable with a marked delay in both bedtime and wake-up time during weekends [45]. Second, a recent study found that weekend sleep compensation could only partially compensate for the weekday sleep debt while the hypothalamic–pituitary–adrenal axis and inflammatory systems remained disrupted [46]. Third, some of those participants with long weekend time in bed (sleep duration) might have comorbid mood problems.

This study also replicated the association of a high prevalence of EDS with excessive media use [12], which could further delay bedtime, exacerbate sleep insufficiency, aggravate insomnia symptoms, and precipitate eveningness chronotype in adolescents [47,48]. We also found that nocturnal sleep problems, including both insomnia and sleep-disordered breathing, would contribute to the occurrence of EDS in the young population [49,50]. Nonetheless, help-seeking behaviors of the young population with sleep problems (eg, insomnia) are very limited [51].

Our present study also found a complex and significant interaction between puberty and chronotype in the modulation of EDS. We found that the prevalence of EDS progressively increased with pubertal maturation, which has a profound impact on the alignment of circadian and sleep–wake processes by shifting the sleep–wake cycle towards eveningness [4,52–57]. The delay in circadian rhythm, coupling with early school start time, may contribute to the sleep deprivation and EDS in adolescents [21]. In this regard, recent genetic studies suggested a genetic component in the chronotype and circadian system [58,59].

The emergence of the female predominance of EDS at mid-puberty was in line with the evidence that EDS is predominant in female adults [15]. The effect of increased gonadal hormones on sleep, mood, and the circadian clock may have a direct or indirect impact on the presentation of EDS [60]. Thus, the cumulative effect of the emergence of insomnia [5], mood problems and eveningness chronotype with pubertal maturation may contribute to the occurrence of EDS in adolescents, especially females.

Moreover, EDS was found to be independently associated with daytime napping, consumption of alcohol and 'energy' drinks, emotional and behavioral difficulties, and poor mental health

[16,21,61], even after sleep disturbances and chronotype effect were taken into account [5,20]. In other words, comprehensive assessment and management of EDS by reducing daytime media use, enhancing nocturnal sleep duration and moderating circadian problems are needed. In this regard, our previous sleep education program has been effective in improving sleep knowledge, and improving behavior and mental health outcomes; but was not able to improve sleep duration [21]. Further interventions such as postponing school start time may be needed to ameliorate EDS and improve the general well-being of children and adolescents [17,62].

The major strength of the present study is a large sample size with both children and adolescents, which allow us to study the effects of different pubertal stages. Several issues should be noted when interpreting the results. First, our cross-sectional study design could not confirm a cause–effect relationship between EDS and these factors. Second, the response rate was only modest, as the student participants in the study were required to give their own written consent and that of their parents or guardians, which may reduce the generalization of this study. Third, parental reports among primary school students may have resulted in a potential reporting bias. Nonetheless, it has been suggested that the report of sleep problems by parents would be more accurate than by self-report for children aged below 12 years [11]. However, we should still note that parents may not be able to accurately assess sleepiness of their children at school, which may underestimate the severity of EDS of their children. Fourth, the pubertal stages were assessed by self-reporting which may potentially lead to report bias, albeit self-report of pubertal stages may be deemed to be appropriate in large-scale studies [25]. Additionally, about 27% of the respondents were unwilling to report their pubertal stage, which might have a potential selection bias of our findings, as students with sexual precocity or delayed puberty may be more reluctant to report their pubertal status.

5. Conclusion

EDS is prevalent among children and adolescents, with a progressive increase across pubertal maturation. Given that a

constellation of complex and interrelated factors may contribute to the high prevalence of EDS, there is a need for families, educational authorities, and health professionals to foster a healthy environment for enhancing sleep health literacy, promoting adequate sleep habits and practices among growing children and adolescents.

Disclosure statement

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Author contributions

Dr. YP Liu conceptualized and conducted the data analyses, drafted the initial manuscript, reviewed and revised the manuscript. Dr. YK Wing conceptualized and designed the study, supervised all the aspects of the research project and critically reviewed the manuscript. Drs. JH Zhang and SX Li managed the data, conducted the data analyses and critically reviewed the manuscript. Ms. NY Chan, Ms. MWM Yu, and Dr. SP Lam designed the data collection instruments, and coordinated and supervised data collection at school sites, and critically reviewed the manuscript. Drs. JWY Chan and AM Li conceptualized and designed the study and critically reviewed 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

Dr. Wing has received sponsorship from Lundbeck Export A/S, Servier Hong Kong Ltd, Pfizer company Ltd, and Celki Medical Company. The other authors have indicated they have no financial relationships relevant to this article to disclose.

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.2018.08.028>.

Appendix A. Supplementary data

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.sleep.2018.08.028>.

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