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ORIGINAL ARTICLE

Sleep duration, wake/sleep symptoms, and academic performance in Hong Kong Secondary School Children

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Abstract
Background Sleep deprivation is common among teenagers. The aim of this study was to investigate the relationship between sleep duration, wake/sleep symptoms, and academic performance among Hong Kong students.
Materials and methods The sleep habit questionnaires were distributed to all Year 11 students at an international school that catered to different ethnic groups in Hong Kong. Analysis of various parameters of academic performance and sleep habits and their relationships were undertaken.
Results Fifty-nine students were recruited. The average sleep duration in this group was 7.23 h. The overall prevalence of excessive daytime sleepiness (defined as an Epworth Sleepiness Scale score of >10) was 25.4%. Eleven subjects had excessive class sleepiness, defined as high likelihood to fall asleep during at least one school session. Mathematics performance was positively correlated with sleep duration. Excessive sleepiness on rising was identified as a significant risk factor for poor performance in English and Mathematics. Sleepiness during the third and fourth lessons was identified as a significant risk factor for poor performance in Mathematics only.
Conclusion Sleep deprivation was common in the studied cohort and it was associated with a decrease in Mathematics performance. Excessive sleepiness on rising and sleepiness during third and fourth lessons were associated with poorer grades in Mathematics and English. Excessive daytime sleepiness was reported in 25% of students. Bruxism and snoring were associated with excessive daytime sleepiness.

Keywords Sleep · Cognition · Adolescents · Sleep deprivation · Snoring

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Introduction

Sleep has been demonstrated to be closely associated with learning and memory consolidation [1]. Hence, it is not surprising that sleep deprivation has been associated with decreased learning efficiency, while sufficient sleep enabled teenagers to perform to their full capacity in a number of studies [2, 3]. Animal studies demonstrated that sleep deprivation disrupted learning of tasks that involve hippocampus [4–6]. Disruption of rapid eye movement sleep produces substantial learning impairments of hippocampus-related tasks, including spatial maze paradigms, one-way and two-way avoidance learning, taste aversion, and passive avoidance tasks. [5, 7, 8] Unfortunately, sleep deprivation is an increasing problem in teenagers. A phone survey by Ng et al. [9] showed that the mean sleep duration of Hong Kong Chinese primary school students was 8.79 h, significantly shorter than the 10 h recorded in American children.

Sleep pattern changes during adolescence, including a decrease in sleep duration [10], a delay in sleep time [11], and an increasingly large discrepancy between weekday and weekend sleep patterns [12]. Pilcher and Huffcut reported that sleep-deprived subjects functioned at a level that was only equivalent to the ninth percentile of non-sleep-deprived subjects [13]. Excessive daytime sleepiness (EDS), a consequence of sleep deprivation, was also

suggested to be related to poor academic performance. Shin et al. [14] conducted a questionnaire survey to evaluate the impact of EDS on academic performance in a group of 3,871 high school students in Korea. They showed that students with higher Epworth Sleepiness Scale (ESS) [15] had lower academic grades. Unfortunately, important confounding factors for academic results, like obstructive sleep apnea syndrome and habitual snoring [9], were not reported by Shin et al.

In the current study, the relationship between sleep duration, sleep/wake symptoms, and academic results was studied. As of writing, no study reported the direct relationship between sleep duration and academic results in Hong Kong.

Materials and methods

All Year 11 (16- to 18-year-olds) secondary school students from the Australian International School Hong Kong were invited to fill in a sleep habit questionnaire (SHQ, "Appendix I"). SHQs were distributed to all Year 11 classes and all completed questionnaires were collected by one of the authors (EPN). The questionnaires asked about the duration, i.e., between lights-out and wake, of sleep the night before. Common sleep problems such as snoring, witnessed apnea, and bruxism were also asked. The SHQ also integrated the ESS to study the severity of excessive daytime sleepiness. ESS is an eight-question questionnaire with a possible score range of 0 (least sleepy) to 24 (most sleepy). An ESS score above 10 is indicative of excessive daytime sleepiness. [15] Three additional questions were included in the questionnaire to assess the degree of sleepiness during class. Class sleepiness was categorized as never, rarely, sometimes, or almost always on the response to the question "Do you get sleepy during the 1st/2nd, 3 rd/4th, 5th/6th lessons?" Excessive class sleepiness (ECS) was defined as almost always sleepy in at least one session.

The questionnaire also included a section in which participants were asked to report their English and Mathematics scores obtained in the preceding semester report. Only the results from English and Mathematics were collected because these two subjects were offered to all students.

Body mass index (BMI) was calculated by dividing the reported body weight in kilograms by the square of reported standing height in meters. BMI was used to quantify the adiposity. In childhood, BMI is influenced by gender and age and changes with age. Although pediatric BMI percentile curves are available, their application in parametric statistical procedures is compromised by the skewed distribution. Hence, an individual's BMI value was transformed to standard deviation score (SDS) based on the gender and age-specific smoothed measure of skewness, median, and the coefficient of variation values of Chinese [16]. As normal values of BMI change with age, BMI standard deviation score (BMISDS) was calculated to allow comparison across different age groups and gender. Obesity was defined as BMISDS>1.96 and overweight was defined as BMISDS>1.64.

Statistical analysis

All analyses were conducted with Statistical Package for the Social Sciences (SPSS Inc, Chicago, IL, USA). Basic data were presented as the mean ± SD for continuous variables (e.g., sleep duration, BMI, etc.) and as percentages for categorical variables. Academic performance was represented by a scale of 1–7, of which 7 is the best grade. Pearson's correlation for continuous variables was computed to assess the association between sleep duration, total ESS score, and the academic grades. If the distribution of score was skewed, non-parametric Spearman's correlation was used. Comparisons involving continuous variables were performed using independent *t* tests. The grades were compared by Student's *t* test between those with or without snoring, allergic rhinitis, asthma, eczema, and bruxism. A Pearson chi-square test was used for assessment of the association between categorical variables, e.g., EDS, ECS, snoring, allergic rhinitis, asthma, eczema, and bruxism. A p value of <0.05 was considered statistically significant and all tests were two-tailed.

Results

Fifty-nine out of 62 eligible subjects returned the completed questionnaires. The subject characteristics and their symptoms were summarized in Tables 1 and 2, respectively. The

Table 1 Basic characteristics of subjects

Subjects, *n*	59
Age (year) mean (SD)	16.5 (0.594)
Sex, female, *n* (%)	28 (47.5%)
Ethnicity, *n* (%)	
Chinese	30 (50.8%)
Caucasian	22 (37.3%)
South Asian	2 (3.4%)
Others	5 (8.5%)
BMI, mean (SD)	21.9 (3.6)
Sleep duration, mean (SD)	7.23 (1.62)
ESS score, mean (SD)	7.6 (4.2)
Mathematics score, mean (SD)	4.16 (1.48)
English score, mean (SD)	4.15 (1.01)

Table 2 Prevalence of symptoms

	N (%)
Feeling on rising	
Refreshed	16 (27.1)
Sleepy	24 (40.7)
Very sleepy	12 (20.3)
No comment	7 (11.9)
Symptoms on rising, *n*	
Tiredness	41 (69.5%)
Headache	19 (32.2%)
Snuffle	17 (28.8%)
Dry mouth	15 (25.4%)
Faint	6 (10.2%)
Class sleepiness i.e. ≥1 session, *n* (%)	11 (18.6%)
Snoring, *n* (%)	
Never	35 (59.3%)
Only with cold	6 (10.2%)
Occasionally without colds	14 (23.7%)
Often	4 (6.8%)
Bruxism	
Never	39 (66.1%)
Rarely	9 (15.3%)
Sometimes	5 (8.5%)
Almost always	4 (6.8%)
Do not know	2 (3.4%)

population consists of three age groups: 15 years (n=3, 5.1%), 16 years (n=35, 59.3%), and 17 years (n=21, 35.6%). As the respondents provided their weight and height, the body mass index were calculated. The mean BMI of all children was 21.9 (SD, 3.6). Two of them were obese, i.e., BMI z score larger than 1.96.

Sleep duration

The sleep duration was normally distributed with no significant skewness. (Kolmogorov–Smirnov test, Z=0.739, p=0.646) The mean sleep duration was 7.23 h across the sample. If one defined significant sleep deprivation as sleep less than 7.3 h, 28 (47.5%) of students in the current study experienced significant sleep deprivation. Seven (11.8%) had severe sleep deprivation, defined by sleep duration of less than 6 h [17]. The sleep duration of non-Chinese (7.53 h, SD=1.02) was comparable with that reported by Steptoe et al. [17], while the sleep duration of Chinese (7.00 h, SD=1.92) was lower, although the difference did not reach significance (p=0.224). Male respondents had a mean sleep duration of 7.45 h (SD, 1.35), whereas female respondents had a lower mean of 7.12 h (SD, 1.75), albeit the difference did not reach statistical significance (p=0.128). Compared with non-Chinese, Chinese students went to bed significantly later (non-Chinese mean bed time, 23:08 ± 1.17 h versus 23:54 ± 1.66 h, p=0.043), but had a comparable wake up time (non-Chinese mean bed time, 06:39 ± 0.47 h versus 06:56 ± 0.79 h, p=0.138). There was no significant correlation between BMISDS and sleep duration (Pearson's correlation, r=−0.001, p=0.996).

Daytime symptoms

Forty-one respondents (n=41) indicated that they experienced tiredness on rising. Other symptoms included headache (n=19), snuffle (n=17), dry mouth (n=15), and light-headedness (n=6). Twelve (23.1%) indicated feeling "very sleepy" on rising in the morning and 24 (46.2%) of the respondents felt "sleepy."

Mathematics and English scores

Both the English and Mathematics scores ranged from 1 to 7, with 7 being the best score. The mean score for English and Mathematics grades were 4.15 (SD, 1.01) and 4.16 (SD, 1.48), respectively. The distribution of Mathematics score was not skewed (one-sample Kolmogorv–Smirnov test, Z=1.2, p=0.114.) However, the score of English was significantly skewed (one-sample Kolmogorv–Smirnov test, Z=2.08, p<0.001).

The Mathematics and English scores were compared between different groups categorized by the following parameters: gender, ethnicity, snoring, bruxism, headache, faint, dry mouth, snuffle, tiredness, allergic rhinitis, asthma, sleepiness in first and second lessons, sleepiness in third and fourth lessons, sleepiness in fifth and sixth lessons, and sleepiness in the morning using one-way analysis of variance (ANOVA) for parameters with more than two categories or Student's t test for parameters with two categories. As shown in the Tables 3 and 4, feeling very sleepy on rising was significantly related to lower scores in Mathematics and English. For English, students who felt very sleepy were more likely to have lower scores than students who felt refreshed (p=0.045) or sleepy (p=0.002). Similarly, for Mathematics, students who felt very sleepy were more likely to have lower scores than students who felt refreshed (p=0.041) or sleepy (p=0.019). Sleepiness in the third and fourth lessons was related to Mathematics scores (Table 3). Students who almost always got sleepy during the third and fourth classes (second session) had lower scores than those who never felt sleepy (p=0.007), but not lower than those who rarely and sometimes get sleepy.

Table 3 Mean Mathematics score and its significant related factors

Factors	Mean score (SD)	*p* value
Sleepiness in the morning		
Refreshed	4.44 (1.21)	
Sleepy	4.52 (1.44)	
Very sleepy	3.25 (1.87)	<0.05[a]
Sleepiness during third and fourth lessons, i.e., second session		
Never	4.86 (1.46)	
Rarely	4.08 (1.43)	
Sometimes	4.05 (1.25)	
Almost always	2.33 (2.31)	<0.007[b]

[a] One-way ANOVA. Students feeling very sleepy in the morning were more likely to have lower Math scores than students feeling refreshed (p=0.041) or sleepy (p=0.019)

[b] One-way ANOVA. Students who almost always felt sleepy had lower Math scores than students who never (p=0.007) felt sleepy

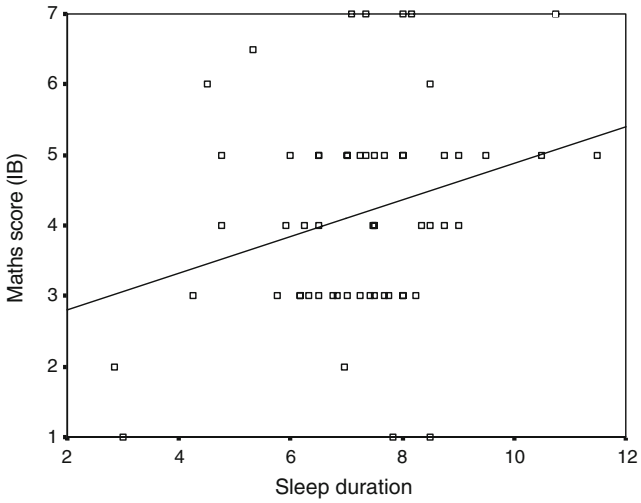

Fig. 1 Correlation between math score and sleep duration

Sleep duration

There was a positive correlation between the Mathematic score and sleep duration (Pearson's correlation, r=0.282, p=0.031; Fig. 1). No significant correlation was found between the English score and sleep duration (ρ=0.211, p=0.318).

Excessive daytime sleepiness

The ESS scores ranged from a maximum of 24 and a minimum of 0, with a mean of 7.6 (SD, 4.20). Similar to sleep duration, the distribution was not significantly skewed (Kolmogorov–Smirnov test, Z=0.868, p=0.438). ESS was used to classify students with EDS. Defining EDS as ESS> 10, the prevalence of EDS among the cohort was 25.4% (n=15). Factors associated with EDS included snoring and bruxism (Table 5). BMISDS was not significantly related to the prevalence of EDS (p=0.669). The mean Mathematics and English scores of children were similar in children with or without EDS (Table 6).

Excessive class sleepiness

Eleven subjects (18.6%) had ECS, defined as at least one session during school day scored as almost always falling asleep. There was no significant association between ECS and EDS (Pearson's chi-square, p=0.091; OR=3.16; 95% CI, 0.8–12.54). Those with ECS did not have a significantly higher ESS than those without (7.1 ± 3.5 vs. 9.6 ± 6.3, p=0.071). This analysis highlighted the inefficiency of the ESS questionnaire in capturing the problem of sleepiness during class. In contrast to EDS, ECS was not related to snoring (p=0.257) nor bruxism (p=0.483). EDS and ECS were also not associated with the academic performance of Mathematics and English, while a more specific time of sleepiness, i.e., third and fourth lesion, predicted a lower grade in both subjects.

Table 4 Mean English score and its significant related factors

Factors	Mean score (SD)	*p* value
Sleepiness in the morning		
Refreshed	4.19 (0.75)	
Sleepy	4.54 (0.88)	
Very sleepy	3.42 (1.38)	<0.05[a]

[a] Friedman's test. Students feeling very sleepy were more likely to have lower English scores than students refreshed (p=0.045) and sleepy (p=0.002)

Discussion

In this study, the mean duration of sleep was less than the current statistical norm of 7.5 h [17]. It was common for bedtime to be delayed for adolescents while rise time remained the same [18]. The findings of this study were similar to previous reports in secondary school students. In the study by Liu et al. [12], the mean sleep duration reported for mainland Chinese students was 7.64 h. In a study by Gau et al. [19], the mean sleep duration was 7.35 h for Taiwan students. In a study by Lazaratou et al. [20], the mean sleep duration for Greek students was 7.5 h. In the current study, 37% of students went to bed at midnight or

Table 5 Factors associated with EDS

	Excessive daytime sleepiness (%)	No excessive daytime sleepiness	OR
Snoring ever			
Yes	11 (48%)	13	6.56 (1.76–24.42)
No	4 (13%)	31	
Bruxism ever			
Yes	8 (44%)	10	3.66 (1.06–12.62)
No	7 (18%)	32	

later and the mean sleep duration was 7.2 h, slightly less than that of similar cohorts of adolescents.

In the current study, a difference in sleep duration was evident between Chinese and non-Chinese students. The mean sleep duration for non-Chinese students was greater than Chinese students, even though the difference did not reach statistical significance (p=0.224) probably because of the small sample size. The difference was similar to that reported by Steptoe [17] who compared sleep duration of teenagers across 24 countries. The mean sleep duration of Taiwan (ethnic Chinese) male and female teenagers were 6.61 and 6.51 h, respectively, positioning Taiwan as the region with the second least sleep duration (Japanese teenagers slept the least). In contrast, regions outside East Asia all reported mean sleep duration above 7 h for both male and females.

Similar to previous studies, the current study showed that a longer sleep duration was related to better Mathematics performance (p=0.031). In the study by Kahn et al. [21], it was reported that school achievement difficulties occurred more frequently in poor than in normal sleepers. A study by Ng et al. [9] showed that primary school students with good academic results slept significantly longer than those with poor academic results. Wolfson and Carskadon [22] studied sleep patterns and daytime functioning in around 3,000 high school students in the USA. They showed that students with better grades reported more total sleep and earlier bedtimes on school nights.

In the current study, the overall prevalence of excessive daytime sleepiness was 25%, higher than that reported by Shin et al. [14] who found EDS in 16% of Korean high school students. Indeed, early school start times, i.e., 0710–0800 hours are the usual start time in Hong Kong school, lead to sleep deprivation and daytime sleepiness [23, 24]. In the current study, EDS was found to be associated with snoring (OR=6.56; 95% CI, 1.76–24.42) and bruxism (OR=3.66; 95% CI, 1.06–12.62). In a study conducted by Gottlieb et al. [25], a progressive increase in ESS score was observed across increasing snoring frequency, from 6.4 in non-snorers to 9.3 in regular snorers. The prevalence of excessive daytime sleepiness increased from 15% in never-snorers to 39% in regular snorers. Gottlieb et al. [25] suggested that "snoring-related arousal caused by increased upper airway resistance or acoustic stimulation" was a likely mechanism for EDS. Henke et al. [26] suggested that increased subjective sleepiness was caused by snoring through arousal-independent mechanisms such as fatigue, which was caused by "increased work of breathing accompanying the higher airway resistance." In a study by Stoohs and Dement [27], sleep deprivation was shown to be a factor that increased the severity of snoring and sleepiness. Therefore, sleep deprivation might be an important confounding factor in the relationship between snoring and excessive daytime sleepiness.

Table 6 EDS and academic results

	EDS	Without EDS	P
Mean Mathematics score (SD)	4.2 (1.5)	4.15 (1.5)	0.907
Mean English score (SD)	4.2 (1.0)	4.1 (1.1)	0.836

While the association between EDS and snoring were well reported [35, 28], no previous studies identified bruxism as a factor for EDS. The current study found that students with EDS were three times more likely to have bruxism. Ohayon et al. [29] did report that bruxism was "associated with moderate daytime sleepiness." However, the degree of sleepiness was measured by a subjective three-point categorical scale, not by the ESS scale as used in the current study. Several studies reported that bruxism was associated with obstructive sleep apnea (OSA) [29, 31]. Ohayon et al. [29] identified OSA as a risk factor for tooth grinding. Sleep arousals induced by OSA, otherwise known as respiratory-event-related arousal (RERA), result in tonic masticatory muscle activation [31]. Motor activation in the masticatory muscles would result in the grinding of teeth, i.e., bruxism. Therefore, the current authors postulate that the RERA leads to bruxism as well as fragmentation of sleep that, in turn, leads to EDS. Further studies are warranted to test this hypothesis.

In the current study, sleepiness during the third and fourth lessons but not during earlier or later lessons was associated with lower Mathematics grades. Students who "almost always" felt sleepy during the third and fourth lessons had significantly lower mean scores for Mathematics compared to those who "never" felt sleepy. This higher discriminatory power of sleepiness during the third and fourth lessons to predict academic achievement, probably through sleep deprivation, was not surprising considering that the sleep latency was highest, i.e., least likely to fall asleep, at 9:30 A.M. and shortest at 3:30 P.M. [30]. So it was unlikely even for those who were sleep-deprived to be sleepy during the first and second lessons, while even those who were not sleep-deprived might feel sleepy for the fifth and sixth lessons that took place after lunch. Sleepiness during the third and fourth lessons (10:50 A.M.–12:50 P.M.) amongst the population could still be related to the circadian rhythm. Further studies are needed to investigate this relationship.

Previous studies showed that increasing daytime sleepiness, as a consequence of poor quality of sleep, could seriously impair students' cognitive functions and behavioral performance [22]. Academic performance was clearly linked to daytime sleepiness [23, 33]; it was shown that the prevalence of excessive daytime sleepiness (ESS score >10) in students with poor grades was 20.5%, which was significantly higher than those with a fair grade (14.2%) and those with a good grade (14%) [14]. Other studies showed that students with more regular sleep–wake patterns (shorter sleep latencies, fewer night awakenings, later school rise times, later rise times on weekends) reported higher school grades [34], whereas students with lower grades reported increased daytime sleepiness with a shorter sleep. Although the current study did not reveal a correlation between EDS and academic performance, the significant association between sleepiness during the third and fourth lessons and academic performance corroborated previous findings. This was further supported by the current finding that performance in both English and Mathematics were associated with the feeling of sleepiness on rising in the morning ($p<0.05$). Previous study by Eliasson et al. [35] found no correlation between sleep duration and academic performance, and we suspected that may possibly be due to the fact that sleepiness was not studied. Further studies about the relationship between sleep duration and academic performance should also analyze the potential effect of daytime sleepiness.

Limitations

The main limitation of the current study was the small sample size of 59 participants. The small number of participants resulted in the increased likelihood of type II error. The data were based entirely on self-reported questionnaires and thus subject to responder bias. Sleep symptoms were likely to be underreported, as the participants might not be aware of their sleep symptoms like snoring and bruxism. Sleep duration was calculated from the reported lights-out and wake times of the single night prior to the completion of the questionnaire and would present a major limitation of the current study. The result would thus likely be subject to systematic bias, i.e., shortened sleep duration across the whole cohort during school day resulting in incomparability with literature. Finally, comparing students from different ethnic backgrounds might be affected by the potential confounding effect of different types of families (authoritarian or permissive style) and different psychosocial commitments (extracurricular activities, social commitments) in different ethnic groups. Failure to take into account these potential confounding factors might introduce biases [34, 36]. These potential biases were partially addressed in the current cohort who attended the same private school, and they were likely to come from similar socioeconomic groups.

Conclusion

The sleep duration in this study is less than the statistical norm by Steptoe et al., and sleep deprivation is common in the studied cohort of high school students. Sleep duration was significantly correlated with Mathematics scores in a positive manner. Teenagers who reported feeling very sleepy on rising were more likely to have lower grades in Mathematics and English, whereas sleepiness during the third and fourth lessons was associated with lower grades in Mathematics only. Bruxism and snoring were associated with excessive daytime sleepiness.

Appendix

Sleep Questionnaire

Name: _____

Class: _____

Date: _____

DOB: __ __ - __ __ __ - __ __ __ __

Weight: _____ kg

Height: _____ cm

What time did you go to bed last night?

__ __: __ __ (am/pm)

What time did you wake up this morning?

__ __: __ __ (am/pm)

How did you feel on rising today?

☐ Refreshed ☐ sleepy ☐ very sleepy

Race: ☐ Chinese ☐ Caucasian ☐ South Asian ☐ African American ☐ Japanese

☐ Korean

Section 1

How often do you snore? (as related to you by parents/guardians or siblings)

c Never

c Only with Cold

c Occasionally without Colds

c Often

How often do you grind your teeth during sleep? (as observed by your parents/guardians or siblings)

c Never

c Rarely

c Sometimes

c Almost always

In the last week, do you have the following problem(s) on rising?

c Headache

c Faint/Vertigo

c Dry mouth

c Snuffle (blocked nose)

c Tiredness

Other: _____

Do you have the following problem(s) diagnosed by your doctors? Please tick if yes.

c Allergic Rhinitis

c Asthma

c Hypertension

c Eczema

Do you get sleepy during the 1st, 2nd lessons?

c Never

c Rarely

c Sometimes

c Almost always

Do you get sleepy during the 3rd, 4th lessons?

c Never

c Rarely

c Sometimes

c Almost always

Do you get sleepy during the 5th, 6th lessons?

c Never

c Rarely

c Sometimes

c Almost always

Section 2

How likely do you doze off or fall asleep in the following situations? This refers to your usual days in the recent few months. In the case of having not encountered such situations, please try to estimate your likelihood of falling asleep under that situation.

Sitting and reading

c No chance of dozing

c slight chance of dozing

c moderate chance of dozing

c high chance of dozing

Watching TV

c No chance of dozing

c slight chance of dozing

c moderate chance of dozing

c high chance of dozing

Sitting inactive in a public place (e.g. a theater or a meeting)

c No chance of dozing

c slight chance of dozing

c moderate chance of dozing

c high chance of dozing

As a passenger in a car for an hour without a break

c No chance of dozing

c slight chance of dozing

c moderate chance of dozing

c high chance of dozing

Lying down to rest in the afternoon

c No chance of dozing

c slight chance of dozing

c moderate chance of dozing

c high chance of dozing

Sitting and talking to someone

c No chance of dozing

c slight chance of dozing

c moderate chance of dozing

c high chance of dozing

Sitting quietly after a lunch without alcohol

c No chance of dozing

c slight chance of dozing

c moderate chance of dozing

c high chance of dozing

A few minutes after sitting down in a vehicle

c No chance of dozing

c slight chance of dozing

c moderate chance of dozing

c high chance of dozing

Section 3

Please indicate the mark you received in the Semester 1 report for:

English:

7 6 5 4 3 2 1

Mathematics:

7 6 5 4 3 2 1

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