School start time and sleep in Canadian adolescents

GENEVIÈVE GARIÉPY[1], IAN JANSSEN[2], MARIANE SENTENAC[1] and FRANK J. ELGAR[1,3]

[1]Institute for Health and Social Policy, McGill University, Montreal, QC, Canada; [2]School of Kinesiology and Health Studies and Department of Public Health Sciences, Queen's University, Kingston, ON, Canada; [3]Department of Psychiatry, McGill University, Montreal, QC, Canada

Keywords
adolescence, school policy, school start times, sleep duration, sleep pattern

Correspondence
Geneviève Gariépy PhD, McGill Institute for Health and Social Policy, 1130 Pine Avenue West, Montreal, QC H3A 1A3, Canada.
Tel.: 514-398-1236;
fax: 514-398-8983;
e-mail: genevieve.gariepy@mail.mcgill.ca

Accepted in revised form 12 October 2016; received 19 April 2016

DOI: 10.1111/jsr.12475

[Correction added on 26 December 2016 after first online publication: In the Discussion section, a sentence contradicting the results has been corrected in this version.]

SUMMARY

Insufficient sleep is a serious problem in adolescents and school start time is thought to be a key contributor. This study provided the first comprehensive assessment of school start times across Canada and examined whether school start times were associated with sleep duration and tiredness among adolescents. We collected information on school start times from 362 schools that participated in the 2013/2014 Health Behaviour in School-aged Children study. We calculated sleep duration from weekday bedtime and wake time reported by 29 635 students (aged 10–18 years). We classified weekday sleep as sufficient if it met national recommendations, and used data on self-reported tiredness at school in the morning. Random-effects regression models estimated the association of school start time with sleep duration, sleep sufficiency and tiredness. On average, schools started at 08:43 hours. Students slept an average of 8:36 h on weekdays and 69% met sleep duration recommendations, but 60% reported feeling tired in the morning. Every 10-min delay in school start time corresponded with 3.2 [95% confidence interval (CI): 2.0, 4.5] additional minutes of sleep, a 1.6% (95% CI: 0.5, 2.8) greater probability of sufficient sleep and a 2.1% (95% CI: 1.0, 3.2) smaller probability of feeling tired at school in the morning. Students from schools that started later slept longer, were more likely to meet sleep recommendations and were less likely to report feeling tired in the morning. The study adds weight to the mounting evidence that delaying school start time benefits adolescent sleep.

INTRODUCTION

Insufficient sleep is an emerging health problem in North American adolescents (Basch *et al.*, 2014; Eaton *et al.*, 2010; Matricciani *et al.*, 2012). The evidence indicates that at least one-third of adolescents do not meet the minimum sleep recommendations of 8–9 h (Tremblay *et al.*, 2016) on weeknights (Basch *et al.*, 2014; Chaput and Janssen, 2016; Eaton *et al.*, 2010; Gibson *et al.*, 2006), and the majority feel tired when they go to school in the morning (Chaput and Janssen, 2016; Gibson *et al.*, 2006). Adolescents that do not get enough sleep do worse academically (Dewald *et al.*, 2010), are more likely to develop mental health problems such as depression, anxiety and suicidal thoughts (Baum *et al.*, 2014; Winsler *et al.*, 2015) and physical health problems such as obesity, diabetes and high blood pressure (Cappuccio *et al.*, 2008; Javaheri *et al.*, 2008), and are more likely to suffer injuries and become involved in car accidents (Danner and Phillips, 2008; Milewski *et al.*, 2014). The health consequences of insufficient sleep impact significantly upon the educational attainment, work achievement and life opportunities of young people.

In 2014, the American Academy of Pediatrics recognized insufficient sleep in adolescents as a critical public health issue and identified school start time as a key determinant (Au *et al.*, 2014). The American Thoracic Society followed suit in 2015 (Mukherjee *et al.*, 2015). Central to the problem is a mismatch between adolescent sleep biology and early school start time. Biological changes during puberty delay the circadian cycle by up to 2 h, resulting in a natural sleep period between 23:00 and 08:00 hours or later (Gradisar *et al.*, 2011). Early school start time is hypothesized to conflict with the delayed circadian rhythms of adolescents, resulting in less sleep. Studies from the United States dating back to 1994 have shown consistently that early school start times correlate with shorter sleep duration in students

(Wheaton *et al.*, 2016). In response to these findings, and with pressure from advocacy groups, several American education institutions changed their school schedules to a later start time (Owens *et al.*, 2014). In their 2014 policy statement, the American Academy of Pediatrics recommended that middle and high schools delay school start time to 08:30 hours or later (Au *et al.*, 2014).

The issue of sleep and school start time has received much less attention in Canada. The Canadian Paediatric Society has not made a recommendation on school start time, although talks on the topic were featured for the first time at the Society's 2015 annual conference (2015). While some Canadian schools have recognized the problem and taken action by delaying school start times (Rushowy, 2011), others have advanced start time as measure to reduce school bussing costs (Nolan, 2012; Outhit, 2013). Political discussions may be limited by the lack of knowledge regarding school start times across Canada and insufficient sleep in the Canadian context. Most of the evidence is based on American studies, and may not be applicable to Canada. For example, cultural and climatological differences between Canada and the United States may influence sleep patterns (Gradisar *et al.*, 2011; Walch *et al.*, 2016).

Changing school start time is a complex undertaking that involves consultation with several stakeholders and considerations of logistic issues (e.g. transportation), human resources and costs—challenges which have been detailed elsewhere (Kirby *et al.*, 2011) and that can be overcome successfully (Owens *et al.*, 2014). A key to this success is timely and contextually relevant data that can inform dialogue and motivate stakeholders and community members to act. The aim of the paper is therefore to provide current information on school start time in a representative sample of Canadian schools and its association with sleep in Canadian adolescents. We hypothesized that early school start time would relate to shorter sleep duration and more tiredness on weekdays.

METHODS

Participants

Data on sleep were collected from the 2013/14 Canadian Health Behaviour in School-Aged Children (HBSC) survey. The HBSC surveyed 30 117 students in grades 6–10 (1320 classes in 367 schools) from all provinces and territories in Canada. The HBSC selected a cluster sample of students by grade and school through weighted probability methods in order to obtain a balanced representation of school population characteristics such as religion, community size, school size and language of instruction. Private schools,[1] special needs schools and schools for youth in custody were excluded from the survey. The HBSC protocol stipulated a standard questionnaire format, item order and testing conditions. Teachers or trained interviewers distributed the questionnaires in classroom settings. The Canadian HBSC was approved by the Queen's University General Research Ethics Board. Consent was obtained from the participating school boards, individual schools, parents and students. Student participation was voluntary. For this study, we excluded students from grades 5 (n = 25), 11 (n = 294) and 12 (n = 5), as they were not the focus of the HBSC and survey weights were unavailable, children younger than 10 years (n = 12), as the focus of the study was on adolescents, and students from three schools where start time was unavailable because the schools were permanently closed (n = 132) and from two schools that had no specific start time (n = 5). The final sample included 29 635 students between the ages 10 and 18 years from 362 schools.

Measures

The HBSC survey asked students what time in the past week they usually turned out the lights and went to sleep and what time they usually awoke on school days and at weekends. We calculated the average sleep duration from the reported bedtimes and wake times. This approach correlates highly with objective sleep measures in children (Matricciani, 2013). We excluded values greater than 3 standard deviations (SD) from the mean (school days: n = 408; weekends: n = 406). Results were unchanged when we included outliers in sensitivity analyses. We classified children as having a sleep duration that was sufficient if they met the sleep requirement based on the 2016 Canadian 24-h Movement Guidelines (5–13-year-olds: 9–11 h; 14–17-year-olds: 8–10 h) (Tremblay *et al.*, 2016). Students were also asked how much they agreed with the statement: 'I am usually tired when I go to school in the morning'. We considered students to experience tiredness when going to school if they 'agreed' or 'strongly agreed' with this statement.

We defined school start time as the start of the first morning class. Information was obtained for all schools through school websites or by contacting school officials directly.

We further included variables that could confound the association between school start time and sleep, including the school grade and family affluence of adolescents and the neighbourhood characteristics, rurality, latitude and province of the schools. Family affluence could affect the choice of school and the associated start time to which students were exposed. The Family Affluence Scale III (Torsheim *et al.*, 2016) asks participants to report on six common indicators of family wealth. Responses were summed (score range: 6–19). A subsample of school administrators (n = 304) were asked about seven neighbourhood problems around their school (racial/ethnic/religious tensions; garbage; drugs or alcohol; gangs; heavy traffic; crime). We counted the number of items

[1]Private schools in Canada are characterized by an alternative teaching curriculum and receive partial or no funding from the provincial government. Between 0.7% (New Brunswick) and 12.6% (Quebec) of school-aged children were enrolled in private schools in 2013 (Van Pelt *et al.* 2015).

reported to be a problem (minor/moderate/major problem versus no problem) as a proxy for school neighbourhood conditions that could influence start time. We identified schools from rural areas based on their alphanumerical postal code (Post Canada, 2016) and obtained information on school latitude by geocoding schools using publicly available geospatial data (http://www.gpsvisualizer.com/geocoder). We further collected information on potential effect modifiers of the relationship between school start time and sleep, including gender, age and grade of participants, travel time to school (<5, 5–15, 16–30, 31–60 or >60 min, based on HBSC response categories) and season of survey (spring: April–June; autumn: September–December; winter: January–March). Fewer students were surveyed during the early autumn months (September: $n = 0$; October: $n = 89$; November $n = 1334$; December: $n = 1909$; total $n = 3332$) than during the winter (January: $n = 2744$; February: $n = 4715$; March: $n = 3112$; total $n = 10\,571$) and spring months (April: $n = 4483$; May: $n = 8575$; June: $n = 2674$; total $n = 15\,732$).

Statistical analysis

We conducted descriptive analyses of the sample. We then fitted school-level random-effects generalized models of school start time separately for sleep duration, sleep sufficiency and morning tiredness as outcomes. We used a linear model for sleep duration and a modified Poisson method for sleep sufficiency and morning tiredness, because these outcomes were common (Petersen and Deddens, 2008). Models were adjusted for grade and family affluence of participants and geographical characteristics of the schools (rurality, latitude, province). We modelled school start time using fractional polynomial modelling to check for non-linearity. We chose to use the linear term for simplicity, as results were almost identical to fractional polynomials (Table S1). We presented the predicted sleep duration (from the linear model) and predicted probabilities (from the Poisson models) for the available range of school start time using the margins commands in Stata. Full information on covariates was available, except for sleep duration (12% missing data), morning tiredness (7%) and family affluence (12%). In sensitivity analysis, missing values were imputed using multiple imputation by chained equations using the mi command. Because information on the neighbourhood environment of schools was collected from only a subsample of school administrators, we adjusted for this variable in a sensitivity analysis. We examined potential effect modifiers of school start time by testing interaction terms in the main model using the Wald test, separately for gender, grade, age, rurality of school, travel time to school and season, and then estimated the average marginal effect of school start time for each value of the effect modifier. In additional analyses, we used bedtime as the outcome in the main regression model to examine its association with school start time and calculated the predicted sleep–wake cycle associated with different school start times. All analyses were weighted using post-stratification weights to ensure that results were representative of public school students in Canada. Statistical analyses were conducted in Stata (version 14.1; Stata Corp, College Station, TX, USA). Survey weights and school-level clustering were handled using Stata's complex survey (svy) commands.

RESULTS

The mean school start time was 08:43 hours (SD: 0:17) and ranged from 07:57 to 09:37 hours. Characteristics of HBSC participants are presented in Table 1. Students slept an average of 8:36 h (SD: 1:16) on weeknights, with an average bedtime of 22:20 hours (SD: 1:08) and wake time of 06:56 a.m. (SD: 0:39). Approximately two-thirds of participants (69%) met the minimum sleep recommendation, but 60% reported feeling tired when going to school in the morning. Students went to bed later, woke up later and slept longer on weekends (Table 1). Sleep characteristics by potential effect modifiers are presented in Table S2. The average sleep duration was related inversely to age, grade and travel time to school. Age and grade related to later

Table 1 Characteristics of participants in the 2014 HBSC survey ($n = 29\,635$)

	Weighted % (n)	*Weighted mean (SD)*
Age (years)		14.1 (1.5)
Sex		
Boys	49.1 (14 542)	
Girls	50.9 (14 940)	
Grade		
6	15.2 (4551)	
7	19.3 (5788)	
8	19.6 (5801)	
9	23.6 (6974)	
10	22.1 (6521)	
Family affluence scale score		15.0 (2.4)
Season of survey		
Spring	68.0 (15 732)	
Autumn	8.3 (3332)	
Winter	23.8 (10 571)	
Sleep pattern on weekdays		
Sleep duration (h:min)		8:36 (1:16)
Bedtime (h:min)		20:20 hours (1:08)
Wake time (h:min)		06:56 hours (0:39)
Meets sleep recommendation	68.8 (17 267)	
Sleep pattern on weekends		
Sleep duration (h:min)		9:45 (1:42)
Bedtime (h:min)		23:47 hours (1:43)
Wake time (h:min)		09:31 hours (1:44)
Meets sleep recommendation	84.5 (21 617)	
Feeling tired going to school in the morning	59.8 (16 637)	

bedtimes, while travel time to school related to early wake times. Sleep duration and early bedtimes related to rurality of the schools and season of survey. No gender differences were found in sleep patterns.

Table 2 shows predicted sleep duration, probability of getting sufficient sleep and probability of feeling tired when going to school in the morning across the range of school start times in the study (results from the regression models are available in Tables S3–S5). These analyses suggest that students who attended a school with an 09:30 hours start time compared with an 08:30 hours start time slept an additional 19 min [95% confidence interval (CI): 11.8, 26.7], had a 7% (95% CI; 2.1, 12.3) higher probability of getting sufficient sleep (75 versus 67%) and a 7% (95% CI: 3.7, 10.7) lower probability of feeling tired when going to school in the morning (61 versus 54%). Every 10 min added to school start time was associated with 3.2 (95% CI: 2.0, 4.5) additional minutes of sleep. The findings were robust to imputed values for missing data (3.3 min, 95% CI: 2.0, 4.5) and remained after adjusting for school neighbourhood problems (3.4 min, 95% CI: 2.0, 4.8).

Associations between school start times and sleep duration did not differ significantly by gender, grade, age, rurality, travel time to school and season (Table 3). However, point estimates suggested that students in grades 9–10 and students surveyed in the autumn had the greatest sleep gain from delayed school start time compared to lower grades and students surveyed in the winter and spring, respectively, whereas students from rural areas and students who travelled for more than an hour to get to school benefited less from a later start time. In additional analyses, we found that later school start time was associated with later school day bedtime (1.9 min for every 10-min delay in school start time, 95% CI: 0.8, 2.9). The average predicted sleep period was 22:29–07:23 hours for students who started school at 09:30 a.m. and 22:17–06:52 hours for those who started at 08:30 a.m. (Table S6).

DISCUSSION

This study examined the association between school start time and adolescent sleep in the Canadian context. Results from a large representative sample of students show that insufficient sleep was a common problem in Canadian students and that approximately one-third did not meet national sleep recommendations, in similar proportions to the United States (Basch *et al*., 2014; Eaton *et al*., 2010). Evidence from this study supports the notion that later school start time is associated significantly with longer sleep duration and fewer students reporting tiredness going to school, in line with previous research from the United States, Australia, Europe and Asia (Short *et al*., 2013; Wheaton *et al*., 2016). Findings suggest that even a small shift in school start time may have a large impact upon the sleep of adolescents at the population-level. Later school start times related to better sleep outcomes regardless of gender, age, grade, travel time to school, rurality of schools and season. The average school in the study started at 08:43 hours, much later than 08:03 hours that was reported recently for schools in the United States (Wheaton *et al*., 2015), but results indicate that delaying start time even further would benefit adolescents in significant ways.

School start time was associated linearly with sleep duration in the sample and suggest that each 10-min delay in start time was associated with an additional 3.2 min of sleep. Although it is reasonable to assume that the benefits of delaying school start time will diminish at a certain point, we found no evidence of a flattening of effect within the range of start times in the study, which varied from approximately 08:00 to 9:30 hours. Indeed, our analyses suggest that the latest 09:30 a.m. start time would benefit adolescents the most by allowing the majority to meet sleep recommendations. Later school start time was also associated with fewer students feeling tired when going to school in the morning. Tiredness could be a reflection of insufficient sleep, but may

Table 2 Adjusted predicted sleep duration, probability of getting sufficient sleep and probability of feeling tired according to school start time in the 2014 HBSC survey (n = 29 635)

School start time (hours)	*Sleep duration (h:min)*	*95% confidence interval*	*Probability (%) of getting sufficient sleep*	*95% confidence interval*	*Probability (%) of feeling tired*	*95% confidence interval*
08:00	8:26	8:21, 8:32	64.2	61.1, 67.3	64.7	62.0, 67.4
08:10	8:30	8:26, 8:34	65.3	62.8, 67.8	63.4	61.3, 65.5
08:20	8:33	8:30, 8:36	66.4	64.4, 68.4	62.0	60.4, 63.7
08:30	8:36	8:34, 8:39	67.5	66.0, 69.1	60.8	59.4, 62.1
08:40	8:39	8:37, 8:42	68.6	67.2, 70.1	59.5	58.1, 60.9
08:50	8:43	8:39, 8:46	69.8	68.1, 71.5	58.3	56.6, 59.9
09:00	8:46	8:42, 8:50	71.0	68.7, 73.2	57.0	55.0, 59.1
09:10	8:49	8:44, 8:54	72.2	69.2, 75.1	55.9	53.3, 58.4
09:20	8:52	8:46, 8:58	73.4	69.6, 77.1	54.7	51.7, 57.7
09:30	8:55	8:48, 9:03	74.6	70.0, 79.2	53.6	50.1, 57.0

Predicted from school-level random-effect regression models, adjusted for grade and family affluence of participants and geographical characteristics of the schools (rurality, latitude, province), and weighted using survey weights.

Table 3 Marginal predicted mean minutes of additional sleep associated with each 10-min delay in school start time, by potential effect modifier

Effect modifier	*Minutes of additional sleep*	*95% confidence interval*	P-*value of interaction term*
Sex			
Boys	3.6	2.2, 4.7	
Girls	3.2	1.7, 4.7	0.653
Grade			
6	1.8	−0.4, 3.9	
7	2.7	0.9, 4.5	0.415
8	1.6	−0.2, 3.5	0.898
9	4.9	2.2, 7.7	0.091
10	4.1	2.2, 5.6	0.107
Age* (years)			
11	3.2	1.1, 5.3	
12	3.1	0.6, 5.6	0.905
13	2.6	0.9, 4.4	0.605
14	3.3	1.4, 5.2	0.943
15	4.7	3.1, 6.4	0.223
16	3.1	0.8, 5.5	0.964
Travel time to school			
<5 min	2.5	1.0, 4.0	
5–15 min	3.5	2.3, 4.7	0.259
16–30 min	3.3	1.7, 5.0	0.392
31–60 min	3.7	0.9, 6.6	0.397
>60 min	1.2	−2.2, 4.6	0.447
Rural area			
Rural	1.7	−1.5, 4.8	
Non-rural	3.5	2.2, 4.7	0.266
Season of survey†			
Spring	3.6	2.1, 5.0	
Autumn	5.5	3.5, 7.7	0.114
Winter	2.1	0.1, 4.0	0.157

The marginal predicted mean minutes were estimated from a school-level random-effect regression model adjusted for grade and family affluence of participants and geographic characteristics of the schools (rurality, latitude, province), and weighted using survey weights. *P*-value of interaction term estimated from Wald test.

*The analysis was conducted for ages 11–16 only because other age groups had small sample sizes (n = 34 for age 10; n = 117 for age 17; n = 22 for age 18). The regression model excluded grade to avoid collinearity.

†Spring: April–June; Autumn: September–December; Winter: January–March.

also be attributed to the circadian-mediated lack of alertness when students are asked to wake and function during times that conflict with their circadian cycle. This might explain partly why fewer than one-third of students did not meet sleep requirements while twice as many (60%) reported being tired in the morning. In this study, the sleep pattern associated with an 09:30 hours school start time mapped onto the natural sleep period of adolescents—typically between 23:00 and 08:00 hours (Gradisar *et al*., 2011)—better than the sleep pattern associated with an 08:30 a.m. start time. These results lend support to the statement from the American Academy of Pediatrics that schools should aim to start classes no earlier than 08:30 hours (Au *et al*., 2014) and to reports from schools in Canada (Rushowy, 2011) that find significant benefits from starting class as late as 10:00 hours. Our study found a delayed bedtime with later school start times, but that was not enough to offset total sleep gains. In contrast, previous studies found no association between later school start time and later bedtime (Lufi *et al*., 2011; Wolfson *et al*., 2007), and some actually found adolescents went to bed earlier (Owens *et al*., 2010; Vedaa *et al*., 2012), although school start times from these studies were often earlier (07:30–08:30 hours) than those in this Canadian sample.

The benefits of later school start time on adolescent sleep extended across different subgroups; however, students in grades 9 and 10 seemed to gain more sleep from later school start time than those in lower grades (6–8). A similar effect modification by age was not observed. Danner and Phillips (2008) also reported greater sleep gains from a 1-h delay in school start time for students in higher compared to lower grades (grade range: 9–12). Additional academic pressure and a heavier homework load could be factors delaying bedtime for students in grades 9 and 10, who might therefore gain more sleep from later school start time compared with lower grades. Rural students in our sample benefited from later school start times less than non-rural students. Paksarian *et al.* (2015) found similar results for adolescent boys from the US National Comorbidity Survey. Our results and those of others (Pereira *et al*., 2010) suggest that adolescents from rural areas go to bed earlier and sleep longer than those from urban areas, supporting an environmental component to sleep patterns. Students who travelled more than an hour to get to school woke up earlier and gained less sleep from later school start time compared to those with shorter travel times, implying that transportation early in the morning might impede sleep gains from later school start time. Finally, students surveyed in late autumn went to bed earlier and gained more sleep from delayed school start time than those surveyed in the winter and spring. The reduced daylight hours in late autumn are thought to lengthen the sleep period, resulting in earlier bedtime and later wake time (Wehr, 1991), which might be accommodated better with later school start time. The same observation can be expected in early winter, but students surveyed in January might have reported past-week sleep patterns associated with their winter break (from approximately 20 December 2013 to 6 January 2014), rather than with their regular school schedule.

The study is the first, to our knowledge, to provide information on school start time and its association with adolescent sleep problems specifically in the Canadian context. The study is strengthened by data from a large representative sample of schools and students from across Canada, use of a random-effects model to account carefully for the correlation between students from the same school and sensitivity analyses to check the robustness of the results. The study also has some limitations. Sleep duration

was estimated from self-reported bedtime and wake time. Latency in sleep onset and night-time awakenings were not measured, which may have led to an over-estimation of sleep duration (Matricciani, 2013). Because the sample included students from grades 6–10, results may not be generalizable to higher grades. The study was cross-sectional and causality cannot be inferred, although school start time may be considered largely exogenous to the sleep patterns of students. Cluster randomized control trials and quasi-experimental study designs could provide more valid inferences. It is noteworthy, however, that prior studies examining the influence of policy changes (Danner and Phillips, 2008) and interventions (Boergers *et al*., 2014; Vedaa *et al*., 2012) have reported results that are consistent with ours.

Insufficient sleep is an important issue among Canadian adolescents. This study provides evidence that students from schools that started later slept longer, were more likely to meet sleep recommendations and fewer were to report feeling tired in the morning than those from schools that started earlier. Similar and consistent evidence has been reported in the United States and elsewhere, and now extends to Canada. School-based sleep promotion programmes and other group-based interventions have been proposed to address sleep problems in adolescents, albeit with limited effectiveness (Cassoff *et al*., 2013). The delay of school start time may be an additional modifiable factor that has the potential to benefit large groups of adolescents. Although changes in school schedule are often complex and challenging (Kirby *et al*., 2011), policymakers and stakeholders are encouraged to consider delaying the start time of schools when addressing sleep problems in youth. Future intervention studies are recommended for specific policy recommendations.

ACKNOWLEDGEMENTS

The Public Health Agency of Canada funded the HBSC study in Canada. The Canadian principal investigators of the HBSC study are Drs John Freeman and William Pickett and its national coordinator is Matthew King. The international coordinator of the HBSC is Dr Joanna Inchley, at the University of St Andrews, Scotland. This paper was also supported by research grants from the Canadian Institutes for Health Research (MOP 235688), the Social Sciences and Humanities Research Council of Canada and the Canada Research Chairs program awarded to FJE and IJ.

CONFLICT OF INTEREST

The authors report no conflicts of interest.

AUTHOR CONTRIBUTIONS

Research question: GG; data collection: GG; data analysis: GG; interpretation of results: GG with contributions from IJ, FJE and MS; manuscript preparation: GG with contributions from IJ, FJE and MS. All authors revised critically and approved the final version for publication.

REFERENCES

Au, R., Carskadon, M., Millman, R. *et al.* School start times for adolescents. *Pediatrics*, 2014, 134: 642–649.

Basch, C. E., Basch, C. H., Ruggles, K. V. and Rajan, S. Prevalence of sleep duration on an average school night among 4 nationally representative successive samples of American high school students, 2007–2013. *Prev. Chronic Dis*., 2014, 11: 5.

Baum, K. T., Desai, A., Field, J., Miller, L. E., Rausch, J. and Beebe, D. W. Sleep restriction worsens mood and emotion regulation in adolescents. *J. Child Psychol. Psychiatry*, 2014, 55: 180–190.

Boergers, J., Gable, C. J. and Owens, J. A. Later school start time is associated with improved sleep and daytime functioning in adolescents. *J. Dev. Behav. Pediatr*., 2014, 35: 11–17.

Canadian Paediatric Society. *Paediatric Conference to Feature Latest Research on Child and Youth Health*, 24 June 2015. MarketWired, Toronto, ON, 2015.

Cappuccio, F. P., Taggart, F. M., Kandala, N. B. *et al.* Meta-analysis of short sleep duration and obesity in children and adults. *Sleep*, 2008, 31: 619–626.

Cassoff, J., Knauper, B., Michaelsen, S. and Gruber, R. School-based sleep promotion programs: effectiveness, feasibility and insights for future research. *Sleep Med. Rev*., 2013, 17: 207–214.

Chaput, J. P. and Janssen, I. Sleep duration estimates of Canadian children and adolescents. *J. Sleep Res*., 2016, 25: 541–548.

Danner, F. and Phillips, B. Adolescent sleep, school start times, and teen motor vehicle crashes. *J. Clin. Sleep Med*., 2008, 4: 533–535.

Dewald, J. F., Meijer, A. M., Oort, F. J., Kerkhof, G. A. and Bogels, S. M. The influence of sleep quality, sleep duration and sleepiness on school performance in children and adolescents: a meta-analytic review. *Sleep Med. Rev*., 2010, 14: 179–189.

Eaton, D. K., Mcknight-Eily, L. R., Lowry, R., Perry, G. S., Presley-Cantrell, L. and Croft, J. B. Prevalence of insufficient, borderline, and optimal hours of sleep among high school students—United States, 2007. *J. Adolesc. Health*, 2010, 46: 399–401.

Gibson, E. S., Powles, A. C., Thabane, L. *et al.* 'Sleepiness' is serious in adolescence: two surveys of 3235 Canadian students. *BMC Public Health*, 2006, 6: 116.

Gradisar, M., Gardner, G. and Dohnt, H. Recent worldwide sleep patterns and problems during adolescence: a review and meta-analysis of age, region, and sleep. *Sleep Med*., 2011, 12: 110–118.

Javaheri, S., Storfer-Isser, A., Rosen, C. L. and Redline, S. Sleep quality and elevated blood pressure in adolescents. *Circulation*, 2008, 118: 1034–1040.

Kirby, M., Maggi, S. and D'angiulli, A. School start times and the sleep–wake cycle of adolescents: a review and critical evaluation of available evidence. *Educ Res*., 2011, 40: 56–61.

Lufi, D., Tzischinsky, O. and Hadar, S. Delaying school starting time by one hour: some effects on attention levels in adolescents. *J. Clin. Sleep Med*., 2011, 7: 137–143.

Matricciani, L. Subjective reports of children's sleep duration: does the question matter? A literature review *Sleep Med*., 2013, 14: 303–311.

Matricciani, L., Olds, T. and Petkov, J. In search of lost sleep: secular trends in the sleep time of school-aged children and adolescents. *Sleep Med. Rev*., 2012, 16: 203–211.

Milewski, M. D., Skaggs, D. L., Bishop, G. A. *et al.* Chronic lack of sleep is associated with increased sports injuries in adolescent athletes. *J. Pediatr. Orthop*., 2014, 34: 129–133.

Mukherjee, S., Patel, S. R., Kales, S. N. *et al.* An official American Thoracic Society Statement: the importance of healthy sleep. recommendations and future priorities. *Am. J. Respir. Crit. Care Med*., 2015, 191: 1450–1458.

Nolan, D. *Alarm Being Sounded on Early Bell Times*. Hamilton Spectator, Hamilton, ON, 2012.
Outhit, J. *Check Here for Changes to Your Child's 2014–15 School Start Time*. Waterloo Region Record, Waterloo, ON, 2013.
Owens, J. A., Belon, K. and Moss, P. Impact of delaying school start time on adolescent sleep, mood, and behavior. *Arch. Pediatr. Adolesc. Med.*, 2010, 164: 608–614.
Owens, J., Drobnich, D., Baylor, A. and Lewin, D. School start time change: an in-depth examination of school districts in the United States. *Mind Brain Educ.*, 2014, 8: 182–213.
Paksarian, D., Rudolph, K. E., He, J. P. and Merikangas, K. R. School start time and adolescent sleep patterns: results from the U.S. National Comorbidity Survey—Adolescent Supplement. *Am. J. Public Health*, 2015, 105: 1351–1357.
Pereira, É. F., Louzada, F. M. and Moreno, C. R. C. Not all adolescents are sleep deprived: a study of rural populations. *Sleep Biol. Rhythms*, 2010, 8: 267–273.
Petersen, M. R. and Deddens, J. A. A comparison of two methods for estimating prevalence ratios. *BMC Med. Res. Methodol.*, 2008, 8: 1–9.
Post Canada Addressing Guidelines. *Section 5: Postal Code*. Post Canada, Toronto, ON, 2016.
Rushowy, K. *Students Thrive With 10 a.m. Start at Toronto High School*. Toronto Star, Toronto, ON, 2011.
Short, M. A., Gradisar, M., Lack, L. C. *et al.* A cross-cultural comparison of sleep duration between US and Australian adolescents: the effect of school start time, parent-set bedtimes, and extracurricular load. *Health Educ. Behav.*, 2013, 40: 323–230.
Torsheim, T., Cavallo, F., Levin, K. A. *et al.* Psychometric validation of the revised family affluence scale: a latent variable approach. *Child Indic. Res.*, 2016, 9: 771–784.
Tremblay, M. S., Carson, V., Chaput, J.-P. *et al.* Canadian 24-hour movement guidelines for children and youth: an integration of physical activity, sedentary behaviour, and sleep. *Appl. Physiol. Nutr. Metab.*, 2016, 41: S311–S327.
Van Pelt, D. N., Clemens, J., Brown, B. and Palacios, M. *Measuring Student Enrolment in Canada*. Fraser Institute, Vancouver, BC, 2015.
Vedaa, O., Saxvig, I. W., Wilhelmsen-Langeland, A., Bjorvatn, B. and Pallesen, S. School start time, sleepiness and functioning in Norwegian adolescents. *Scand. J. Educ. Res.*, 2012, 56: 55–67.
Walch, O. J., Cochran, A. and Forger, D. B. A global quantification of 'normal' sleep schedules using smartphone data. *Sci. Ad.*, 2016, 2: e1501705.
Wehr, T. A. The durations of human melatonin secretion and sleep respond to changes in daylength (photoperiod). *J. Clin. Endocrinol. Metab.*, 1991, 73: 1276–1280.
Wheaton, A. G., Ferro, G. A. and Croft, J. B. School start times for middle school and high school students—United States, 2011–12 school year. *Morb. Mort. Wkly Rep.*, 2015, 64: 809–813.
Wheaton, A. G., Chapman, D. P. and Croft, J. B. School start times, sleep, behavioral, health, and academic outcomes: a review of the literature. *J. School Health*, 2016, 86: 363–381.
Winsler, A., Deutsch, A., Vorona, R. D., Payne, P. A. and Szklo-Coxe, M. Sleepless in Fairfax: the difference one more hour of sleep can make for teen hopelessness, suicidal ideation, and substance use. *J. Youth Adolesc.*, 2015, 44: 362–378.
Wolfson, A. R., Spaulding, N. L., Dandrow, C. and Baroni, E. M. Middle school start times: the importance of a good night's sleep for young adolescents. *Behav. Sleep Med.*, 2007, 5: 194–209.

SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article:

Table S1. Predicted sleep duration according to school start time in the 2014 HBSC Survey (*N* = 29 635), by model for school start time.

Table S2. Sleep characteristics during weekdays, by effect modifier.

Table S3. Estimates from the school-level random-effect linear regression model of sleep duration.

Table S4. Estimates from the school-level random-effect poisson regression model of sleep sufficiency (6–13 years olds: 9 h or more; 14–17 years old: 8 h or more).

Table S5. Estimates from the school-level random-effect poisson regression model of feeling tired when going to school.

Table S6. Adjusted predicted wake time and bedtime according to school start time in the 2014 HBSC survey.