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Sleep duration change among adolescents in Canada: Examining the impact of COVID-19 in worsening inequity

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A B S T R A C T

Purpose: The purpose of this study was to assess if adolescent sub-populations in Canada (i.e., based on race/ethnicity, sex/gender, socioeconomic status, and urbanicity groups) experienced a larger change in sleep duration and guideline adherence between 2019 and 2020 (pre-pandemic) and the 2020–2021 (mid-pandemic) school years.

Methods: Longitudinally linked data from 2019 to 2020 (pre-pandemic) and 2020–2021 (mid-pandemic) of a prospective cohort study of secondary school students (M = 14.2, SD = 1.3 years, *N* = 8209) in Canada were used for analyses. Regression modelling tested the main effects of race/ethnicity, sex/gender, socioeconomic status, and urbanicity on changes in sleep duration as well as adherence to Canada's 24-h Movement Guidelines for sleep (8–10 h/night). Interactions between identity variables (race/ethnicity or sex/gender) and other main effect variables were subsequently tested.

Results: Females gained more sleep (4.5 [1.5, 7.5] min/day more) and increased guideline adherence (AOR = 1.16 [1.04, 1.30] than males on average. Asian race/ethnic identity was associated with less sleep gain than White identity −10.1 [-19.4, −0.8], but not guideline adherence. Individuals in large urban areas gained less sleep and adhered less to guidelines than individuals from any other level of urbanicity (−21.4 [-38.5, −4.2] to −15.5 [-30.7, −0.2] min/day). Higher individual SES scores were associated with greater sleep gain (linear trend: 11.16 [1.2–21.1]). The discrepancies in sleep gain and guideline adherence between males and females were significantly modified by race/ethnicity and urbanicity.

Discussion: Increases in sleep duration may be one of the few benefits to adolescents during the COVID-19 pandemic but were not equally distributed across sub-populations. Efforts to promote better sleep adherence may need to account for sex/gender differences, especially in less urbanized areas and certain racial/ethnic groups.

1. Introduction

There is a recognized need for further longitudinal and population-level research to understand the ongoing impact of the Coronavirus disease 2019 (COVID-19) pandemic on adolescent sleep. COVID-19 mitigation strategies (e.g., school closures, transition to virtual learning, physical distancing) contributed to learning interruptions, social isolation, disruptions in routine, and the cancelation of extracurricular activities (Duan et al., 2020; Partinen et al., 2021). Confinement at home during the early pandemic response has been linked to both positive and negative changes in children's and adolescents' sleep, specifically in terms of delaying sleep and wake times, increased nightmares, or longer sleep duration (Liu et al., 2021). Globally, sleep problems during early COVID-19 were reported in 15–21% of the general population (including both adults and adolescents), and sleep problems were related to higher levels of psychological distress

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(Alimoradi et al., 2021a). Understanding potential sustained and inequitable impacts is critical, as insufficient sleep patterns in adolescence often persist into young adulthood (Hansen et al., 2005). In the short term, lack of sleep and sleep disturbances in adolescents are associated with psychological distress, worse mental health, poor school performance, alexithymia and risk taking behaviours (Alimoradi et al., 2022; Medic et al., 2017; Pengpid & Peltzer, 2022). Furthermore, adequate sleep is associated with better physical, social, and mental health and development in adolescents, and reduced risk of chronic diseases and all-cause mortality across the lifespan (Carson et al., 2017; Chaput et al., 2016; Faulkner et al., 2020; Medic et al., 2017; Ross et al., 2020; Tremblay et al., 2016).

Insufficient sleep is common in adolescents and is considered a public health concern (Michaud & Chaput, 2016; Owens et al., 2014). While the ideal amount of sleep may vary from one person to another, the *Canadian 24-h Movement Guidelines* recommend that adolescents aged 14–17 years get an average of 8–10 h of uninterrupted sleep per day to maintain optimal daytime functioning (Hirshkowitz et al., 2015; Michaud & Chaput, 2016; Tremblay et al., 2016). In nationally representative surveys conducted before the COVID-19 pandemic, about one-third of Canadian adolescents (Chaput & Janssen, 2016; Michaud & Chaput, 2016) and over 60% of U.S. ninth-grade students reported sleeping less than recommended, and these rates increased over the course of high school (Kann et al., 2017). A natural circadian shift towards delayed sleep onset occurs at puberty, which contributes to later bedtimes in adolescents (Carskadon, 2002). Typically, delayed bedtimes contribute to declines in sleep with increasing age over adolescence, as early school start times prohibit sleeping in (Carskadon, 2002).

Remote learning has been found to benefit some adolescents' sleep, as they did not have to wake up early to commute to school (Gruber et al., 2021). In addition, the cancelation of extracurricular activities and the need to socially isolate meant that adolescents had more "useable hours" during the weekdays to complete their homework and did not have to sacrifice sleep to fulfill their obligations during the week (Gruber et al., 2021). In Canadian cross-sectional studies, 72% of youth aged 12–17 years were meeting sleep duration guidelines during the early COVID-19 outbreak (Moore et al., 2020); adolescent sleep duration was longer and their daytime sleepiness was reduced during the pandemic compared to pre-pandemic (Gruber et al., 2021; Ramos Socarras et al., 2021). A scoping review of literature on the impact of the first year of the COVID-19 pandemic on movement behaviours in school-aged children (aged 5–11) and youth (aged 12–17) identified 55 studies assessing sleep behaviours (Paterson et al., 2021a). Some studies suggested that sleep duration had increased in children and youth, and bed and wake times had shifted later, but this evidence was inconsistent. Further, only seven of the studies were prospective in design and most relied on retrospective reports. One prospective study of Canadian adolescents published after this review reported a 42.5 min/day increase in sleep duration on average during the early outbreak of the pandemic compared to the prior year (Duncan et al., 2022). While sleep duration improved during the early pandemic when schools were closed to in-person learning, limited prospective research has explored whether changes were sustained or rebounded during the ongoing pandemic response.

Inequities are understood as not created by social identities, but by the meaning they have due to interdependent social processes and structures of oppression and power (e.g., racism) (University of New MexicoLopez et al., 2016). At an individual level, chronic psychosocial stress has been proposed as one potential mechanism contributing to disrupted sleep among individuals from lower socioeconomic positions (e.g., financial worry (Papadopoulos & Sosso, 2023)), racial minorities (e.g., racial discrimination vigilance, vicarious racism (Chae et al., 2021; Hicken et al., 2013)) (Chae et al., 2021), and girls (e.g., more frequent exposure to stressor (Franco et al., 2020), gender based discrimination (Bell & Juvonen, 2020)). Youth may experience psychological stress through direct exposure to such discrimination, or indirectly through a stressful family environment (Tsai et al., 2018) due to these mechanisms. issues of structural discrimination such as pervasive segregation, lack of access to acceptable housing, and lack of access to health services may also contribute to racial and socioeconomic differences in sleep behaviours through environmental factors (Johnson et al., 2022; Papadopoulos & Sosso, 2023; Weinstein et al., 2017). While Canada has codified multiculturalism and non-discrimination based on race, ethnicity, sex or gender (Cotter, 2019), racialized Canadian youth (Okoye et al., 2023) and girls (Girl Guides of Ontario, 2018) still report experiencing higher rates of discrimination compared to White youth and boys respectively. Furthermore, structural factors contribute to worse health outcomes and unequal access to public services for racialized Canadians (Dryden & Nnorom, 2021; Tuyisenge & Goldenberg, 2021).

Racialized and ethnic minority populations appear disproportionately impacted by COVID-19, including in their risk of mortality (Heidinger et al.); however, limited research has explored whether changes in sleep vary by sub-populations of adolescents. Before the pandemic, a Canadian study found that longer sleep durations occurred in adolescents who identified as male and white, and attended schools in rural areas and with higher median household incomes (Patte et al., 2017). The pandemic potentially reinforced existing sleep disparities and may amplify future health inequalities. A US study found that African American children who are worse off financially had more sleep/wake problems than those with more financial resources, whereas no such effects were found for European American children (Guglielmo et al., 2018). Familial economic hardship has been linked to adolescents' subjective sleep quality, difficulties falling asleep, and shorter sleep duration (Bao et al., 2016; Zheng et al., 2012). During the early outbreak of COVID-19, a higher prevalence of sleep problems among girls has been consistently reported (Alimoradi et al., 2021b; Fu et al., 2020; Robillard et al., 2021). A Canadian online survey found that the emergence of sleep difficulties was more common in girls, and young people with more family responsibilities and earlier wake-up times (Robillard et al., 2021).

There remains a need for longitudinal data to describe changes in sleep duration beyond the early pandemic outbreak period and identify any disproportionate impacts to inform an equitable recovery response (Paterson et al., 2021b). Existing research tends to focus on one factor in documenting health inequities; however, individuals occupy multiple overlapping social positions. The purpose of this analysis was to assess which sub-population (based on interactions of race/ethnicity, sex/-gender, socioeconomic indicators, and urbanicity) experienced larger change in sleep behaviours from 2019 to 2020 (before the onset of the pandemic) to the 2020–2021 school year (during the 2nd and 3rd waves of the COVID-19 pandemic in Canada (Wu et al., 2021)) in a prospective cohort of adolescents living in Canada. We expected that the COVID-19 pandemic would worsen inequities so the sleep duration gains would be less seen in racialized adolescents, girls, and those coming from lower SES backgrounds.

2. Methods

2.1. Design & data collection

Longitudinally linked student-level data from year 8 (Y8, 2019–2020) and year 9 (Y9, 2020–2021) of the Cannabis, Obesity, Mental health, Physical activity, Alcohol, Smoking, and Sedentary behaviour (COMPASS) study were used. COMPASS collects data annually from a rolling cohort of students attending a convenience sample of secondary schools across Canada; the primary purpose of the study is to track changes in multiple youth health behaviours and outcomes over time, to allow for the evaluation of natural experiments by simultaneously tracking changes in school programs, policies, or built environment (Leatherdale, Brown, & Carson, 2014). Data from annual administrations are linked using a series of items to create a unique code

for each respondent that ensure anonymity while allowing COMPASS researchers to link each student's data across years (Qian, Battista, Bredin, Brown, & Leatherdale, 2015). The Y8–Y9 longitudinally linked sample from consisted of 8274 students from 41 schools. Students were excluded prior to analysis if their reported education year did not follow typical progressive levels of education (missing n = 32, "other" n = 33), resulting in 8209 students eligible for analysis.

The COMPASS study received ethical approval from the University of Waterloo Human Research Ethics Committee (ORE#30118), Brock University Research Ethics Committee (REB#18–099), CIUSSS de la Capitale-Nationale–Université Laval (#MP-13-2017-1264), University of Alberta Research Ethics Office (Project #00040729), University of British Columbia (Ref No. H17-00167), and participating school boards. Additional details regarding study methods can be found online (www.compass.uwaterloo.ca) or in print (Leatherdale, Brown, & Carson, 2014). Student-level data were collected using the COMPASS student questionnaire. Prior to school closures related to the early outbreak of COVID-19 in Canada (up to March 12th, 2020), questionnaires used a paper optical mark recognition survey designed to collect student-reported data from full school samples during one classroom period. Subsequently, student questionnaires were adapted to online administration. Schools emailed students an initial survey link and one reminder. All students attending participating schools were invited to participate using active-information passive-consent parental permission protocols, which are critical for collecting robust data among youth (White et al., 2004; Thompson-Haile, Bredin, & Leatherdale, 2013). Students could decline to participate at any time. Recruitment methods are detailed further by Reel and colleagues (Reel, Bredin, & Leatherdale, 2018).

2.2. Measures

2.2.1. Sleep duration

The Y8 paper student questionnaire asked how much time participants usually spend per day sleeping, with response options ranging from 0 to 585 min in 15-min increments. Scores below 180 min/day were deemed to be improbably low outliers (Gilchrist et al., 2021; Duncan, et al. 2022), and winsorized to 180 min/day. At Year 8 n = 441 students and at Year 9 n = 17 reported values below 180 min/day.

Due to fewer space constraints with online delivery and to gather more detailed sleep data in subsequent surveys the Y9, student questionnaire replaced the Y8 sleep item with items asking participants to indicate "During the past week, what time have you usually turned out the light and gone to sleep?" and "During the past week, what time have you usually woken up in the morning" in 15 min increments, on both "weekdays" and "weekends". Self-reported sleep- or bedtimes and wake times are a common methodology for capturing sleep data in children and youth, with correlations with actigraphy often above 0.4 [56]. The difference between wake and sleep-time was used to calculate typical weekday and weekend sleep duration; possible scores ranged from 0 to 1425 min. A weighted average (5 weekdays, 2 weekend days) was used for average daily sleep duration at Y9. Due to the Y9 score ranges responses above the Y8 ceiling of 585 min/day, scores were winsorized to match the response range possible at Y8 survey when performing analysis of longitudinal change. This approach assumes that individuals who were accruing more than 585 min would have rounded down to this maximum value if the response options had remained consistent (as opposed to another response approach such as leaving the response blank). Of longitudinally linked participants, 13.8% (n = 1140) had scores >585 min; affected scores were reduced by a mean (SD) of 42.7 (71.0) min/day; however, 56.0% of cases were reduced by 30 min/day or less. Sleep duration was assessed continuously as well as dichotomized based on whether reported time was meeting Canadian 24-Hour Movement Guidelines for youth 14–17 years, which recommend 8–10 h of sleep per night.

2.2.2. Predictors of interest

Individual demographic variables available for comparison included sex/gender, race/ethnicity, socioeconomic status (SES), and urbanicity of the school region. The survey asked, "are you a male or a female?" and included the response options: *male*, *female*, *I describe my gender in a different way*, and *I prefer not to say*. However, due to low frequencies in the longitudinally linked data, the latter two responses were excluded from analyses. Race/ethnicity responses allowed individuals to select all that apply of: *Asian*, *Black*, *Latin American/Hispanic*, *White* or *Other*; individuals who identified multiple options (n = 585, 52.1% of which indicated both *White* with *Other*) or selected no options (n = 23) were recategorized as "Other". A SES composite score was derived from four items added to the Y9 student survey: i) whether they sometimes go to bed hungry because there is not enough money to buy food (yes = 0, no = 1), ii) perceived familial financial comfort relative to an average student in their class (more comfortable = 2, as comfortable = 1, less comfortable = 0), iii) whether they have their own bedroom (yes = 1, no = 0), iv) whether they were worried about their family paying bills due to COVID-19 (true/mostly true = 1, neutral or don't know/false/mostly false = 0). Individuals scoring a 0 were reclassified as a 1 due to low frequency (n = 4) resulting in a 5 to 1 scale where 5 represents higher SES and 1 represents lower SES. Urbanicity classifications (rural, small urban, medium urban, or large urban) were extracted from Statistics Canada's 2016 census data (Statistics Canada, 2021) based on school postal codes.

2.2.3. Confounding variables

All models controlled for education year of the student, province, self-reported school mode (in person, online, or hybrid), number of days between observations, and regional median annual incomes based on school postal codes from Statistics Canada's 2016 census data (Statistics Canada, 2021) were categorized as ≤$40,000 (approximately national median income level (Statistics Canada, 2531)), $40,001 to $60,000, $60,001 to $80,000, and >$80,000.

2.3. Statistical analysis

Statistical analysis was conducted with R*Studio (R version 4.2.1 (R Core Team, 2020)). Regression models were used to assess changes in sleep duration and odds of meeting sleep duration guidelines, using an analysis of covariance approach (Dalecki & Willits, 1991), where Y9 measures of behaviour were adjusted for the Y8 baseline measure of the same behaviour (in addition to other confounding variables and variables of interest) which can be interpreted to represent differences in change between groups (Dalecki & Willits, 1991). Using the *lme4* package (Bates et al., 2015), multilevel linear regression with a random intercept to adjust for school clustering modeled sleep duration using maximum likelihood variance estimation. However, multilevel logistic models of sleep duration guideline adherence failed to converge when evaluating interactions. As the intraclass correlation coefficient (ICC) of the random intercept for the main effect model was 0.02 for sleep guidelines all logistic models were re-specified without random intercepts to avoid convergence issues and keep analysis consistent. Categorical predictor variables were dummy coded while ordinal variables were orthogonal polynomial coded. Squared scaled generalized variance inflation factor (Fox & Monette, 1992) was below 2 for all variables, thus collinearity was deemed acceptable.

Model testing involved two stages. In the first stage, main effects models were generated where Y8 behaviours, confounding variables, and predictors of interest were included as regressors. Type II analysis of variance using the likelihood-ratio χ^2 statistic from the *car* package (Fox et al., 2019) was used to evaluate omnibus group differences in the main effect models. In the second stage interactions were evaluated between sex/gender or racial/ethnic identity and all other predictors of interest and racial/ethnic identity and all other predictors of interest, interaction models were compared to the nested main effects models using a

likelihood ratio test and the Akaike Information Criterion (AIC).

Post hoc comparison tests were conducted using the *emmeans* package (Lenth, 2019) for statistically significant main effects and interactions that were statistically significant and had a lower AIC than the main effects model. The Benjamini-Hochberg (Benjamini & Hochberg, 1995) correction for the false discovery rate was used to adjust p-values. Main effect differences were assessed post hoc using pairwise comparisons. As all variables of interest were categorical in nature, post hoc comparison tests for interactions were determined a priori to limit the number of comparisons to those that best align with the goal of comparing whether gaps in demographic factors differed under interacting conditions. Where interactions with sex/gender were identified, comparisons evaluated whether the disparity between males and females was statistically different based on pairwise comparisons of the interacting variable. Interactions with race/ethnicity were evaluated as to whether the disparity between the modal identity group (White identifying individuals) and other identity groups were statistically different based on the interacting variable. For all other interacting variables pairwise group comparisons were conducted. The number of comparisons in the test family is provided in subscript. Sensitivity analyses excluding rather than winsorizing sleep duration <180 min/day found a similar direction of effects, although the magnitudes were attenuated.

3. Results

3.1. Participants

After excluding cases where self-reported sex/gender was neither male nor female (n = 68) or missing (n = 13) the resultant analyzed sample size was N = 8128 longitudinally linked students from 41 schools. Mean (SD) age of the sample at Y8 was 14.2 (1.3) years. Regression models used pairwise exclusion for missing data resulting in 7299 with complete cases. Variables used in analyses are described in Table 1 for the analyzed sample (including missing rates) as well as pairwise complete data included in regression analyses.

3.2. Main effects

Table 2 summarizes analysis of variance tests for between group differences for all main effects models. Group differences in sleep duration and sleep guideline adherence were identified for nearly all variables of interest except for SES score for guideline adherence. Estimated marginal means for groups from the main effects model are illustrated for all variables of interest in Fig. 1, and omnibus significant group differences are highlighted in black.

3.2.1. Sex/Gender

Compared to males, females accrued more sleep duration (Δ = 4.5 [1.5, 7.5] min/day, z = 2.9, p = 0.003) and were at greater odds to meet sleep guidelines (AOR = 1.16 [1.04, 1.30], z = 2.6, p = 0.010).

3.2.2. Race/ethnicity

Post hoc tests found that students identifying as Asian accrued less sleep duration than individuals identifying as White (Δ = −10.1 [−19.4, −0.8] min/day, z = 3.0, $p_{adjust10}$ = 0.023), but no other pairwise comparisons were statistically significant. Despite detecting an omnibus difference, post hoc tests found no significant differences between racial/ethnic groups in odds of meeting sleep guidelines at Y9 after adjusting for false discovery.

3.2.3. SES score

Post hoc tests between SES score categories found that individuals with an SES score of 2 accrued less sleep than those scoring a 5 (Δ = −10.3 [−21.1, 0.5] min/day, z = 2.7, $p_{adjust10}$ = 0.037) or a 4 (Δ = −12.5 [−22.8, −2.2] min/day, z = 3.4, $p_{adjust10}$ = 0.007). A linear trend was observed: 11.16 [1.2–21.1], t(7269) = 2.2, p = 0.028; but no higher order trends were significant.

Table 1
Sample characteristics.

	Analyzed Sample (N = 8128)		Pairwise Complete (N = 7299)	
Variable	N/Mean	%/*SD*	N/Mean	%/*SD*
Province				
AB	296	3.6%	269	3.7%
BC	1075	13.2%	905	12.4%
ON	2545	31.3%	2230	30.6%
QC	4212	51.8%	3895	53.4%
Education Year (Y8)*				
Secondaire 1	1271	15.6%	1164	15.9%
Secondaire 2	1020	12.5%	947	13.0%
9/*Secondaire 3*	2481	30.5%	2220	30.4%
10/*Secondaire 4*	2193	27.0%	1965	26.9%
11/*Secondaire 5*	1110	13.7%	962	13.2%
12	53	0.7%	41	0.6%
Sex/gender				
Female	4604	56.6%	4184	57.3%
Male	3524	43.4%	3115	42.7%
Race/ethnicity				
Asian	694	8.5%	588	8.1%
Black	108	1.3%	83	1.1%
Latin	129	1.6%	118	1.6%
White	6218	76.5%	5666	77.6%
Other	979	12.0%	844	11.6%
Urbanicity				
Large Urban	3226	39.7%	2881	39.5%
Medium Urban	922	11.3%	793	10.9%
Rural	2535	31.2%	2274	31.2%
Small Urban	1445	17.8%	1351	18.5%
Median Income				
≤$40,000	634	7.8%	575	7.9%
$40,001–60,000	1218	15.0%	1076	14.7%
$60,001–80,000	4144	51.0%	3661	50.2%
>$80,000	2132	26.2%	1987	27.2%
SES Score				
5 (High)	1753	21.6%	1717	23.5%
4	4027	49.5%	3952	54.1%
3	1268	15.6%	1224	16.8%
2	346	4.3%	336	4.6%
1 (Low)	72	0.9%	70	1.0%
Missing	662	8.1%		
School Mode (Y9)				
In Person	2119	26.1%	1900	26.0%
Mixed	2516	31.0%	2254	30.9%
Online	3460	42.6%	3145	43.1%
Missing	33	0.4%	1900	26.0%
Y8 Sleep Duration				
min/day	453.3	(99.3)	455.2	(97.7)
<480 min/day	3476	42.8%	3070	42.1%
≥480 min/day	4637	57.0%	4229	57.9%
Missing	15	0.2%		
Y9 Sleep Duration				
min/day	505.0	(70.9)	505.2	(70.4)
<480 min/day	2291	28.2%	2156	29.5%
≥480 min/day	5447	67.0%	5143	70.5%
Missing	390	4.8%		
Y9–Y8 Sleep Change	50.8	102.3	50.0	(101.2)
Days Between Observations	458.8	(59.9)	460.0	(59.8)

Note: Analyzed sample includes all longitudinally linked students after exclusions. Pairwise complete data is all cases without missing data. *Secondary education in Quebec consists of *Secondaire 1–5* at which point secondary education ends; *Secondaire* years are listed with the equivalent Grade systems used elsewhere in Canada where data were collected. Y8 = Year 8 (baseline), Y9 = Year 9 (follow-up), SES = Socio-economic status, Sleep Duration values reflect scores after censoring improbably low outliers (<180 min/day) and values at Y9 above the Y8 detection range (>585 min/day).

3.2.4. Urbanicity

Post hoc tests found individuals from large urban regions accrued significantly less sleep than individuals from any other area: large vs

Table 2
Main effects models test results for omnibus group differences.

Variable	*df*	Sleep Time		Sleep Guidelines	
		χ (Partinen et al., 2021)	*p*	χ (Partinen et al., 2021)	*p*
Sex/gender	1	8.6	**0.003**	6.6	**0.010**
Race/ ethnicity	4	13.4	**0.009**	9.7	**0.046**
SES Score	4	16.9	**0.002**	5.5	0.240
Urbanicity	3	12.9	**0.005**	26.1	**<0.001**

Note: SES = Socio-economic status, Results are for type II analysis of variance tests of omnibus group differences for variables of interest within the main effect model, in addition to the listed variables of interest, models adjusted for prior (Year 8) behaviour, education year, province, days between observation periods. *p*-values <0.05 are bolded. In addition to the listed variables of interest, models adjusted for prior (Year 8) behaviour, education year, province, school mode and length of time between observation periods. P-values <0.05 are bolded. N = 7299 pairwise complete cases.

medium urban (Δ = −21.4 [−38.5, −4.2] min/day, z = 3.3, $p_{adjust6}$ = 0.006); large vs small urban (Δ = −16.0 [−30.6, −1.3] min/day, z = 2.9, $p_{adjust6}$ = 0.012); or large vs rural (Δ = −15.5 [−30.7, −0.2] min/day, z = 2.7, $p_{adjust6}$ = 0.015). No differences were detected between medium urban, small urban, and rural regions.

Individuals in large urban areas were also at lower odds to meet sleep guidelines compared to individuals from medium urban (AOR = 0.53 [0.38, 0.75], z = 4.9, $p_{adjust6}$ < 0.001), small urban (AOR = 0.63 [0.47, 0.86], z = 4.0, $p_{adjust6}$ < 0.001) or rural areas (AOR = 0.71 [0.53, 0.95], z = 3.1, $p_{adjust6}$ = 0.004). No differences were significant between individuals from medium urban, small urban, and rural regions.

3.3. Interaction effects

Table 3 summarizes statistical comparisons of interaction models against the main effects model. For both sleep duration and sleep guideline models allowing for an interaction between sex/gender and race/ethnicity and between sex/gender and urbanicity represented a statistically significant improvement and lower AIC compared to the main effects model. The model with the sex/gender by race/ethnicity interaction had the lowest AIC of all models examined for both sleep time and sleep guideline adherence. Estimated marginal means and male-female sex/gender discrepancies by levels of race/ethnicity and urbanicity are presented in Table 4.

3.3.1. Gender and race/ethnicity

Compared to the White reference category, female-male sex/gender discrepancies in sleep time differed significantly for Asian (z = −3.4, $p_{adjust4}$ = 0.0031), Latin (z = −2.1, $p_{adjust4}$ = 0.046), and Other (z = −3.1, $p_{adjust4}$ = 0.005) identifying individuals; sex/gender differences appear to be reversed with males accruing more sleep than females. There was no significant difference between Black and White respondents (z = 0.5, $p_{adjust4}$ = 0.591).

The female:male odds of meeting sleep guidelines differed significantly between Asian and White individuals (= −2.7, $p_{adjust4}$ = 0.014), and between Other and White individuals (z = −3.6, $p_{adjust4}$ = 0.001).

3.3.2. Gender and urbanicity

Among pairwise comparisons between urbanicities of the female-male sex/gender discrepancy, the only difference emerged between large and small urban residents (z = −3.9, $p_{adjust6}$ = 0.001), where the sex/gender discrepancy was greater in small urban areas. Comparisons between large urban and rural residents (z = −2.2, $p_{adjust6}$ = 0.060) and

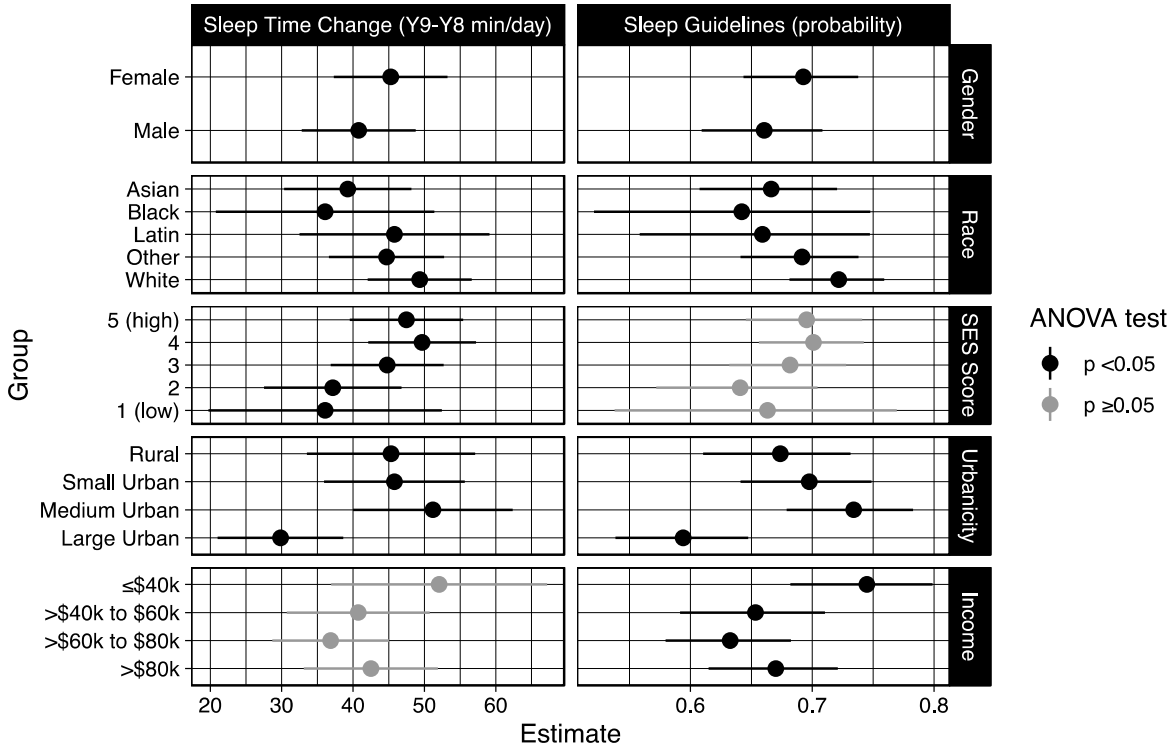

Fig. 1. Model estimated sleep duration change and guideline adherence by group from main effects model.
Note: SES = Socioeconomic status, Income = regional median income. N = 7299 pairwise complete cases. Estimated means for a given outcome are all derived from the same regression model and thus adjust for prior (Year 8) behaviour, education year, province, length of time between observation periods, sex/gender, race, SES score, school delivery mode, urbanicity, and regional median income. Estimates of sleep time change (Y9–Y8) are measured in minutes/day and additionally account for school level clustering. Estimates of sleep guideline adherence represent the probability of meeting Canadian 24-Hour Movement Guidelines for sleep duration time at Y9 (8–10 h/day); clustering was not accounted for in guideline models due to lack of model convergence. Significant omnibus group differences reported in Table 2 are depicted in black, estimates for non-significant group differences are visualized in grey.

Table 3
Model comparisons of interaction models against the main effects model.

		Sleep Time			Sleep Guidelines		
Interaction	*df*	χ (Partinen et al., 2021)	*p*	*AIC*	χ (Partinen et al., 2021)	*p*	AIC
Main Effect Model				81359.7			7769.5
Sex/Gender X Race/ethnicity	4	22.6	**<0.001**	**81345.1**	18.9	**<0.001**	**7758.6**
Race/ethnicity X SES score	16	18.2	0.315	81373.5	11.9	0.753	7789.6
Race/ethnicity X Urbanicity	12	9.4	0.671	81374.3	7.1	0.851	7786.4
Sex/Gender X SES Score	4	2.1	0.726	81365.6	6.4	0.169	7771.0
Sex/Gender X Urbanicity	3	16.4	**<0.001**	**81349.4**	13.0	**0.005**	**7762.5**

Note: SES = Socio-economic status. Meeting sleep guidelines meant accruing ≥480 min/day of sleep on average. N = 7299 pairwise complete cases. Results are for likelihood ratio comparisons of interaction models against the nested main effect model, in addition to the listed variables of interest, models adjusted for prior (Year 8) behaviour, education year, province, days between observation periods. *p*-values <0.05 are bolded.

Table 4
Comparison of estimated marginal means for significant interactions with sex/gender discrepancy in sleep behaviours.

		Estimated Mean [95%CI] by Sex/Gender			Interaction		
Outcome	Interaction	Females	Males	Female-Male	Difference	z	$p_{adjusted}$
Sleep Time Change (Y9 – Y8 min/day)	*Race/Ethnicity*						
	White	53.2 [45.9, 60.6]	45.3 [37.8, 52.7]	7.9 [4.6, 11.3]	Reference		
	Asian	35.5 [25.8, 45.3]	46.5 [35.5, 57.4]	-10.9 [-21.4, −0.4]	-18.9 [-29.9, −7.9]	-3.4	0.003
	Black	43.9 [23.5, 64.3]	28.4 [7.9, 48.9]	15.5 [-11.8, 42.7]	7.5 [-29.9, −7.9]	0.5	0.591
	Latin	38.2 [21.3, 55.1]	55.3 [37.1, 73.5]	-17.1 [-40.1, 5.9]	-25.1 [−48.3, −1.9]	-2.1	0.046
	Other	42.4 [33.6, 51.2]	48.9 [39.5, 58.4]	-6.5 [-15.2, 2.2]	-14.5 [-23.7, −5.2]	-3.1	0.005
	Urbanicity						
	Large Urban	29.2 [20.4, 38.1]	31.2 [22.2, 40.3]	-2.0 [-6.8, 2.8]	Reference*		
	Medium Urban	51.5 [39.9, 63.1]	51.0 [39.0, 63.0]	0.5 [-8.5, 9.5]	-2.5 [-12.7, 7.7]	-0.5	0.634
	Small Urban	51.0 [41.1, 61.0]	38.9 [28.8, 49.0]	12.1 [6.8, 17.5]	-14.1 [-21.3 -7.0]	-2.2	0.060
	Rural	48.4 [36.5, 60.4]	41.2 [29.2, 53.3]	7.2 [0.4, 14.1]	-9.2 [-17.6, −0.9]	-3.9	0.001
Sleep Guidelines (Y9 probability)		**Females**	**Males**	**$AOR_{Female:Male}$**	**AOR Ratio**	**z**	**$p_{adjusted}$**
		0.75 [0.71, 0.78]	0.69 [0.65, 0.73]	1.32 [1.16, 1.50]	Reference		
	Asian	0.65 [0.58, 0.71]	0.70 [0.63, 0.77]	0.78 [0.55, 1.12]	0.59 [0.41, 0.87]	-2.7	0.014
	Black	0.71 [0.55, 0.83]	0.57 [0.4, 0.73]	1.81 [0.70, 4.64]	1.37 [0.53, 3.55]	0.6	0.574
	Latin	0.67 [0.53, 0.78]	0.66 [0.51, 0.78]	1.05 [0.47, 2.32]	0.79 [0.36, 1.78]	-0.6	0.574
	Other						0.001
	Urbanicity						
	Large Urban	0.59 [0.53, 0.65]	0.61 [0.55, 0.66]	0.94 [0.80, 1.12]	Reference*		
	Medium Urban	0.76 [0.7, 0.81]	0.71 [0.64, 0.77]	1.297 [0.95, 1.77]	0.73 [0.51, 1.03]	-1.8	0.229
	Small Urban	0.74 [0.68, 0.79]	0.65 [0.58, 0.71]	1.53 [1.24, 1.88]	0.62 [0.47, 0.81]	-1.1	0.403
	Rural	0.69 [0.62, 0.75]	0.66 [0.58, 0.73]	1.14 [0.85, 1.53]	0.83 [0.59, 1.16]	-3.5	0.003

Note: CI = Confidence Interval, AOR = Adjusted odds ratio of meeting guidelines for females compared to males within strata. AOR ratio represents how much larger or smaller the within strata AOR is compared to the reference strata. N = 7299 pairwise complete cases. Estimated means adjust for prior (Year 8) behaviour, education year, province, regional median income, school delivery mode, days between observation periods, sex/gender, race, SES score, and urbanicity. Estimates of sleep time change (Y9–Y8) are measured in minutes/day and additionally account for school level clustering. Estimates of sleep guideline adherence represent the probability of meeting Canadian 24-Hour Movement Guidelines for sleep duration time at Y9 (8–10 h/day) P-values reported are adjusted for false discovery rate using the Benjamini-Hochberg approach: 4 comparisons for Race/Ethnicity against the White modal response and 6 pairwise comparisons for Urbanicity. *While post hoc comparisons for urbanicity were conducted pairwise, only comparisons against large urban residents are reported for simplicity; comparisons of medium vs small, small vs rural, and rural vs medium were all non-significant ($p_{adjusted}$ = 0.06 to 0.56).

between medium and small urban residents (z = −2.2, $p_{adjust6}$ = 0.060) followed a similar pattern where the sex/gender discrepancy was greater in the less dense area but failed to reach statistical significance.

Comparisons between urban regions of female:male odds of meeting guidelines similarly only found a significant difference between large and small urban residents (z = −3.5, $p_{adjust6}$ = 0.003). No other comparisons were statistically significant.

4. Discussion

This study provides prospective evidence of differences in sleep duration changes from before the COVID-19 pandemic response to the first full school year after by sex/gender, race/ethnicity, socioeconomic context, and urbanicity, in a Canadian cohort of secondary school students. Research from the early lockdown period revealed increased sleep durations among adolescents (Duncan et al., 2022; Gruber et al., 2021; Paterson et al., 2021a; Ramos Socarras et al., 2021), likely due to students not having to wake up early to commute to school. The current study indicates that sleep gains were sustained into the ongoing pandemic response among Canadian adolescents, despite a loosening of COVID-19 mitigation measures in some areas and contrary to the sleep declines that are typically seen with increasing age throughout secondary school. However, sleep gains were not distributed equally across the population. Females gained more sleep and increased guideline adherence than males on average, and individuals in large urban areas gained less sleep and adhered less to guidelines. Higher individual SES scores were associated with greater sleep gain (but not guideline adherence). Asian race/ethnic identity was associated with less sleep gain than White identity. The discrepancies in sleep gain and guideline adherence between males and females was significantly modified by race/ethnicity and urbanicity. Group differences ranged from 4.5 to 21.4 min/day which is comparable to the effect of cognitive and behavioral interventions to improve sleep in school-age children and adolescents who are experiencing sleep difficulties (Blake et al., 2017; Åslund et al., 2018).

While both males and females appeared to increase their sleep time,

female identity was associated with more sleep gain than males. Prior to the pandemic, sex/gender-based differences among Canadian adolescents were mixed (ParticipACTION Report Card on Physical, 2022, p. 86; Patte et al., 2017). Data from the present analysis suggest that if a gender gap existed it may only have widened by about 5 min/day. However, this small change was sufficient to lead girls to be at 1.16 times greater odds to meet guidelines at Y9 compared to boys, and adds up to a 30-min difference across the week. A contributing factor to this difference may be that males tended to adopt more recreational screen time than females during the pandemic, potentially at the cost of additional sleep time (Drumheller & Fan, 2022; Duncan et al., 2022; Leatherdale & Ahmed, 2011; Robillard et al., 2021). However, these findings were not consistent across racial identities, where estimates suggest that while female identifying students experienced greater gains in sleep duration among White individuals, this trend is reversed among Asian and Latino identifying individuals with males tending to gain more sleep than females. Interestingly, these differences in time change do not translate to differences in guideline adherence among Latino individuals, possibly due to wide confidence intervals or this may represent Latino males catching up to their female counterparts over this time period. The reversal of the female-male sex/gender gap among Asian individuals relative to White individuals may reflect different cultural influences. Regardless, more research is needed to better understand the effects of the pandemic on Black and Latino members of the population due to small sample sizes in the current longitudinally linked data, especially given that current effect estimates, and sex/gender interactions suggest that treating these individuals as one category may ignore important differential effects.

The relationship between sleep and student SES scores seem to indicate that individuals with higher SES tended to gain more sleep. Previous Canadian research has found shorter sleep among adolescents attending schools in areas with lower household incomes (Patte et al., 2017), students may live outside of their school area and in areas that differ socioeconomically; with school closures ongoing in some regions, school area income may not be as meaningful. Also, regional income does not account for cost-of-living differences between regions; thus, individual items contributing to the SES score are likely a better indication for this purpose. The composite score results are in the direction expected, given the greater stressors experienced by lower SES families during the COVID-19 pandemic, due to factors such as financial losses, crowded households, and increased food and job insecurity.

Individuals from large urban areas gained the least sleep by 15.5–21.4 min/day and had lower odds of meeting guidelines after adjusting for initial status. Small urban areas were associated with the greatest sex/gender discrepancy, with males lagging behind females in terms of both change in sleep time and guideline adherence; rural areas appear to follow a similar pattern of sex/gender discrepancy. Males and females in large urban areas appear to be doing equally poorly compared to other regions. The overall disadvantage observed for individuals living in large urban areas may reflect more ambient noise as economic activity and commuters returned to the city, as well as easier opportunities to socialize in person as social distancing recommendations relaxed. Prior to the pandemic, Canadian adolescents living in rural and small urban areas reported longer sleep durations than their peers in larger urban areas (Papadopoulos & Sosso, 2023).

Much of the existing literature on sleep changes among youth in response to COVID-19 examined the experiences in the early outbreak (Duncan et al., 2022; Gruber et al., 2021), which reflects rapid changes in response schools moving to provisional online delivery and various psychological stressors related to the emergence of a pandemic. This study examines later behaviours that may reflect the development and stabilization of habits, especially as school resumed more robust lesson delivery. This longer view of behaviour change is likely to better reflect the health behaviour status of youth as societies adapt to the continued presence of COVID-19. On that note, school delivery mode is likely a major contributing factor toward sleep behaviours given the impact school start times can have on sleep accumulation in youth (Gruber et al., 2021); and this was adjusted for statistically. Further strengths include the longitudinal retrospective nature of the COMPASS study which allowed us to examine changes in sleep duration, and the nature of the analysis approach which allowed group sociodemographic differences to be evaluated while simultaneously adjusting for other main effects.

Unfortunately, sleep duration was the only aspect of sleep available longitudinally; changes in sleep quality or wake/bedtimes are other important factors that could contribute to health, and there is evidence that these aspects had been affected during the course of the pandemic (Alimoradi et al., 2021b; Bao et al., 2016; Fu et al., 2020; Guglielmo et al., 2018; Robillard et al., 2021; Zheng et al., 2012). The changes to the Y9 student survey will allow the COMPASS study to better assess more aspects of sleep habits going forward but posed a challenge for analysis. One concern is that time in bed is likely a longer period than time spent asleep (Matricciani, 2013), which may inflate the amount of sleep as operationalized in this study. While all participants received the same surveys, group difference in time spent in bed without sleep may have contributing to group differences in reported sleep. Additionally, the differences in the response range for sleep duration between Y8 and Y9 had to be reconciled; the choice to winsorize Y9 had minimal impact on scores and maximized the available sample size, which was important given small samples of Black and Latino identifying individuals. A further limitation related to small samples was the inability to assess more diverse gender identities than female or male longitudinally; further research on the experiences of gender diverse, Black, and Latino students in Canada is warranted. Finally, while this analysis demonstrates that rates of sleep duration change may have varied by group, no reference group used to compare whether these effects were more pronounced during COVID-19 than what would be typically observed in a given year. As a result, it is not possible to ascribe effects purely to COVID-19 related experiences, but nonetheless, they capture important patterns in sleep behaviour that have emerged among Canadian adolescents.

In terms of movement behaviours, increases in sleep duration appear to be one of the few benefits to adolescents during the COVID-19 pandemic. This evidence suggests that even when environmental changes are conducive to increases in sleep duration, certain population segments will not benefit to the same extent. While no group decreased the amount of sleep acquired, certain population groups appeared to benefit more than others. Sex/gender, race/ethnicity, SES and urbanicity appear to demonstrate significant but modest group differences. Lower SES individuals, Asian identifying, and large urban dwelling adolescents appeared to gain the least sleep compared to their peers, three subpopulations that tended to exhibit shorter sleep prior to the pandemic. The mechanisms causing these differences likely represent a combination of individual level barriers and structural inequalities. In general, more research is needed to understand the mechanisms driving sleep inequality based on sociodemographic factors (Ross et al., 2020); this study helps identify specific populations of Canadian youth that should be the focus of research and suggests that mechanism may differ based on intersections between demographic groups. Understanding such mechanisms will help to tailor public health messaging and identify ways to facilitate structural change.

Based on the results of this study, public health resources to promote sleep hygiene among youth may be best targeted towards Asian males, males living in less urbanized areas, and youth living in large urban centres regardless of gender. This may be especially relevant to individuals who developed a habit of later bedtimes in exchange for more recreational screen time in response to not having to commute to school and have not changed this behaviour since returning to school. While there is limited feasibility in enacting widespread individual level interventions, cognitive behavioural interventions to reduce sleep disturbances in youth with insomnia have demonstrated efficacy (Blake et al., 2017; Åslund et al., 2018) and cognitive behavioural elements such as

sleep education, self-tracking, and developing relaxation techniques can be integrated into health education. Understanding the demographic factors associated with sleep disruption may also help teachers, school counselors and other support staff identify individuals who would most benefit from of referral to more specialized care that can promote better sleep hygiene.

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Declaration of competing interest

None.

Data availability

Data will be made available on request.

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