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Chronic sleep disturbance, not chronic sleep deprivation, is associated with self-rated health in adolescents☆

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ABSTRACT

Improving our understanding of the cumulative effects of persistent sleep problems on adolescent health has been identified as an important area of research. This prospective study aimed to ascertain prospectively gender-specific associations between quantity and quality of sleep and self-reported health. Data from a cohort of 3104 adolescents (13–18 y) with repeated measures of sleep deprivation and sleep disturbance (2011 fall, 2012 spring, 2012 fall), and self-reported health (SRH) (2011 fall, 2012 fall) were analysed with multivariable logistic regression models adjusted for confounders. The results of the regression models indicated that cumulative exposure to sleep disturbance was monotonically associated with SRH in both genders, however cumulative sleep deprivation was not associated with self-reported health among young people. Young women reporting chronic exposure to sleep disturbance had over twice the odds of reporting sub-optimal health at follow-up (OR 2.18 [CI95: 1.13, 4.22]), compared to those with no history. Similar results were found in chronically sleep disturbed young men (OR 2.41 [1.05, 5.51]). These findings suggest that chronic exposure to impaired quality of sleep, such as difficulty falling or staying asleep, is related to adolescent self-reported health and thus may be an important determinant of young people's wellbeing.

1. Introduction

Research into the role sleep plays on the health of adolescents has experienced rapid growth over the past decade (Crowley et al., 2018). Recent scientific consensus recommends that teenagers should sleep between 8 and 10 h per 24 h to optimise health and well-being (Hirshkowitz et al., 2015; Paruthi et al., 2016). However, many do not meet guidelines, with estimates from 17% up to 70% of adolescents sleeping 8 h or less (Chaput and Janssen, 2016; Olds et al., 2010; Wheaton et al., 2016; Morioka et al., 2013). While most health research is focused on the impact of reduced sleep quantity (i.e., duration), young people also commonly report having poor quality sleep. Notably, 10–45% experience sleep disturbances including difficulty falling asleep or inability to stay asleep throughout the night (Morioka et al., 2013; Guo et al., 2014; Kronholm et al., 2015). The high prevalence of inadequate quantity and poor quality of sleep has remained unchanged, or increased, in recent years (Kronholm et al., 2015; Keyes et al., 2015; de Ruiter et al., 2016), presenting a significant current and future public health concern for adolescents.

It is well known that sleep matters for overall health and wellbeing (Paruthi et al., 2016). Inadequate sleep quantity and poor sleep quality affect many health outcomes, including mental health (e.g. anxiety, depression, worry), cardiometabolic risk factors (e.g. BMI, blood pressure, hypertension, insulin resistance), and pain (Shochat et al., 2014; Medic et al., 2017; Chaput et al., 2016). Specific components of sleep that have been linked to young people's higher likelihood of reporting excellent health include sleeping more than 9 h, ease of falling asleep, and restful sleep (OR 1.8–2.1) (Segura-Jiménez et al., 2015). Sleep problems not only affect young people's self-rated health (SRH), but also lowers school performance and increases risk-taking behaviours

Abbreviations: BASUS, British Columbia Adolescent Substance Use Survey; BC, British Columbia; BMI, body mass index; CESD, Centre for Epidemiological Studies Depression Scale; MCAR, missing completely at random; OR, odds ratio; SRH, self-rated health; TH2K, Teen Health 2000

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(Do et al., 2013; Mahon, 1995; Erginoz et al., 2004; Holmström et al., 2014; Roberts et al., 2002). Sleep was recently reported to be a strong upstream determinant of SRH in Australian youth, more than other behaviours examined (fruit and vegetable intake, physical activity, and substance use) (Craig et al., 2018). Although existing evidence makes a compelling case for sleep as a determinant of adolescent health, most studies measure exposure to short sleep or poor sleep using a single time point, which does not elucidate the impact of prolonged exposure to sleep deficits on health and wellbeing. Recent evidence has found that prolonged exposure to adverse experiences, such as persistent financial hardship, may have severe implications for obesity (Conklin et al., 2014). Prolonged exposure to low levels of sleep quantity and quality may also have severe impacts on SRH.

Health promotion efforts targeting young people require sound evidence from robust study designs to prioritize and inform intervention development. The current evidence base relies on cross-sectional studies using single measures of sleep quantity or quality (Segura-Jiménez et al., 2015; Do et al., 2013; Mahon, 1995; Erginoz et al., 2004), whereas longitudinal studies are needed to more fully understand the complex mechanisms at play (Kuo et al., 2014; Roberts et al., 2009). Furthermore, a large knowledge gap exists on gender-specific relationships between sleep and health—a problem for programming since young women and young men experience distinct biological and social processes of differentiation and thus gender is a fundamental determinant of their SRH (Holmström et al., 2014; Vingilis et al., 2002; Bauldry et al., 2012). This study adds new information to the literature on how prolonged exposure to deficits in sleep quantity and quality impact adolescents' SRH and whether show a different pattern for young women and men.

We used longitudinal data from a youth cohort in British Columbia (BC), Canada to ascertain prospectively the associations of persistent deficits in sleep quality and quantity with adolescents' SRH using a gender perspective. We hypothesised that chronic sleep deprivation (cumulative poor quantity) and chronic sleep disturbance (cumulative poor quality) would be associated with sub-optimal health in young people, and that relationships would vary by gender.

2. Methods

2.1. Study population

The BC Adolescent Substance Use Survey (BASUS) was a prospective population-based cohort study investigating psychosocial and environmental factors associated with substance use among youth aged 13–18 years. Initial recruitment of participants was conducted in 48 participating public secondary schools across BC and increased to 86. Students viewed a brief presentation about the study in a classroom or auditorium and school personnel distributed information packages to students to review with their parents/guardians. All participants provided informed consent, as well as written parental consent in schools which required parental consent. School-specific response rates varied (2–100%) and the average was 20%. Online surveys were administered biannually from October 2009 to December 2012 (Schwartz et al., 2014), and this study used the last three waves of self-reported data on sleep duration and sleep quality (Wave 5/Fall 2011, Wave 6/Spring 2012, Wave 7/Fall 2012), SRH (Wave 7/Fall 2012) and socio-demographics (Wave 5/Fall 2011). BASUS was approved by the University of British Columbia's Behavioural Research Ethics Board (# H08-02841).

2.2. Measures

2.2.1. Self-rated health status (SRH)

SRH is the primary outcome as it significantly predicts mortality across population subgroups in Canada up to 14 years before death (Falconer and Quesnel-Vallée, 2017), and is associated with many aspects of adolescent health (Vingilis et al., 2002). SRH was assessed at Wave 7/Fall 2012 using a single question ('In general, how would you rate your health?') with response options on Likert scale (poor, fair, good, very good, or excellent). Responses were dichotomized into 'excellent' vs. 'rest' for the purpose of the analysis similar to other work (Cavallo et al., 2015). 'Excellent' served as the reference category to compare adolescent participants who reported being in optimal health with those in sub-optimal health. The use of a SRH question appears to capture a holistic view of health among adolescents, with girls highlighting stressors (Joffer et al., 2016), and is reported to measure the same construct among different ethnicities of adolescents and young adults (Allen et al., 2016).

2.2.2. Chronic sleep deprivation

We assessed chronic sleep deprivation by total hours of sleep calculated from self-reported sleep and wake times on school nights. We constructed a binary variable for sleep deprivation at survey Wave 5 (Fall 2011), Wave 6 (Spring 2012), and Wave 7 (Fall 2012) to classify participants as sleep deprived (< 8 h) or not (≥ 8 h) according to the National Sleep Foundations guidelines for adolescents (Hirshkowitz et al., 2015). Dichotomised variables contributed to a three-level exposure variable of cumulative sleep deprivation (exposed at only one time-point), occasional (exposed at only one time-point), and no history of sleep deprivation (not exposed at any time-point).

2.2.3. Chronic sleep disturbance

We assessed chronic sleep disturbance by the weekly occurrence of restless sleep, with possible responses of 'rarely or none of the time' (< 1 day), 'some or a little of the time' (1–2 days), 'occasionally or a moderate amount of the time' (3–4 days), and 'most or all of the time' (5–7 days) (Radloff, 1977). We classified participants at all three time-points (Wave 5/Fall 2011, Wave 6/Spring 2012, Wave 7/Fall 2012) as being exposed to poor sleep (≥ 1–2 days) or not (< 1 day) to use the binary variables for constructing a three-level exposure variable of cumulative sleep disturbance involving a reference group (at no time-points), occasional exposure (only one time-point), and chronic exposure (two or more time-points).

2.2.4. Covariables

We accounted for multiple known confounders using self-reported data at study baseline (Wave 4/Spring 2011 height and weight, Wave 5/Fall 2011 socio-demographic variables). Key covariables included: Body mass index (BMI kg/m^2, continuous), ethnicity (White (reference), Asian, Aboriginal, or Other (Latino, Black, and Other)), and family income as perceived relative to peers (far above average/quite a bit average (reference), slightly above, average, slightly below, quite a bit below/far below).

2.3. Statistical analyses

Descriptive statistics summarised baseline socio-demographic characteristics and health outcomes across levels of prolonged exposure to deficits in sleep quantity and quality. A correlation coefficient matrix assessed the inter-relationship of the two unique exposure (independent) variables (cumulative sleep deprivation and cumulative sleep disturbance). The a priori strategy for main analyses was to examine two types of cumulative sleep problems (cumulative sleep deprivation and cumulative sleep disturbance) in relation to SRH (dependent variable) for gender-specific associations (gender as an effect modifier). We ran a series of multivariable logistic regressions to predict SRH, with Model A including a cross-product term between independent variables (cumulative sleep deprivation and cumulative sleep disturbance) and the self-reported female/male variable (male = 0, female = 1) and sequentially conditioning on baseline BMI (Model B), ethnicity (Model C) and family income (Model D). Each model was duplicated using reverse coding for the male/female variable (female = 0, male = 1) to provide estimates for both reference

groups and generate gender-specific results that are generalisable to the entire original sample. The final sample size was 3104.

2.3.1. Missing data

We used multiple imputation to impute missing data for all study variables since complete case analyses can reduce statistical power and bias standard errors. We computed 10 imputations assuming missing at random and using a monotone pattern of missing values in SPSS version 24 software. Results from Little's MCAR test confirmed there were no systematic patterns of missingness ($p = 0.192$) (Little, 1988). Our imputation model included the outcome (SRH), and baseline sleep duration, restless sleep, male/female, ethnicity, family income, mother's education, BMI, pubertal stage, scores on the Centre for Epidemiological Studies Depression scale (CESD) (Radloff, 1991), and several auxiliary variables (age, sugary and caffeinated drinks, internet use, extracurricular sports, tobacco use, quality of life, language spoken at home, and country of birth), which is recommended to reduce bias and increase efficiency of the imputation model (Dong and Peng, 2013).

2.3.2. Sensitivity analysis

We performed separate sensitivity analyses to determine the robustness of our findings to inclusion of other baseline confounders (Wave 4/Spring 2011 health conditions, Wave 5/Fall 2011 socio-demographic and health variables). We also adjusted main models for mother's education (undergraduate/graduate degree, college/trades, high school, some high school), pubertal stage (post-pubertal, late pubertal, mid-pubertal, early puberty, pre-pubertal) (Carskadon and Acebo, 1993), CESD scores (continuous), and health conditions (Attention Deficit Disorder/Attention Deficit Hyperactivity Disorder, asthma, epilepsy, headaches, infection, painful menses, stomach issues). We used pubertal stage to control for potential confounding by development-related weight change (Rogol et al., 2002), constructed from questions related to female/male pubertal development following an established method (Carskadon and Acebo, 1993). We re-specified the cumulative sleep disturbance model using a less stringent threshold (0–2 days/week) for classifying sleep disturbance. To check the impact of ignoring clustering on schools, we re-analysed results using complete cases (range: 660–1030) with and without adjustment for clustering using a generalized estimating equation (GEE) model with robust/sandwich estimator, specified for the binomial family, logit link function and exchangeable correlation matrix.

Descriptive statistics were performed using SPSS and inferential statistics were conducted using Stata version 14.2 (StataCorp LP, College Station, TX). Results are reported as odds ratios (OR) and 95% confidence intervals (CI95).

3. Results

Our sample's mean age was 14.8 years (SD 0.7). About half were female (53%), White (51%), and reported a health condition in the previous year (54%). Around 40% of participants reported their mothers were university-educated and 42% reported relatively high family income. Although a fifth (22%) of young people reported excellent health, a similar proportion (28%) were exposed to sleep deprivation; 17% reported occasional and 11% reported chronic sleep deprivation over 12 months. Prolonged deficits in sleep quality were very common (85%) in our sample, with 23% reporting occasional and 61% reporting chronic sleep disturbance. Chronically poor sleep was weakly related to chronic sleep deprivation ($r = 0.08$).

Table 1 shows a clear social gradient in the distribution of participant characteristics across levels of cumulative sleep deprivation and cumulative sleep disturbance. A larger proportion of participants with chronic sleep problems were female, had lower socioeconomic status, reported an existing health condition, and were depressed. Moreover, sub-optimal health was reported by a higher proportion of adolescents exposed to chronic sleep deprivation (84%) and chronic sleep disturbance (81%) than those with no history (respectively, 76% and 70%).

3.1. Chronic sleep deprivation and odds of sub-optimal health, by gender

Table 2 shows there was no consistent relationship between cumulative sleep deprivation and SRH in young people; sequentially adjusted models demonstrated no change in the effect size with each additional confounder. Sensitivity analyses with other additional confounders showed similar results (Supplementary Table S1). However, associations were stronger and significant for young women when only complete cases were analysed. Specifically, young women reporting occasional sleep deprivation had over four times the odds of sub-optimal health at follow-up (OR 4.77 [CI95: 1.42, 15.97]), compared to those reporting no history of sleep deprivation (Table S2).

3.2. Chronic sleep disturbance and odds of sub-optimal health, by gender

There was a consistent pattern of monotonic increase in the likelihood of sub-optimal health with cumulative sleep disturbances in both young women and young men (Table 3). In multivariable-adjusted models, young women experiencing chronic sleep disturbance over a year were approximately twice as likely to report sub-optimal health (OR 2.18 [1.13, 4.22]) compared to counterparts reporting no history of sleep disturbance. The association was stronger in young men: those reporting chronic sleep disturbance were almost 2.5 times as likely to report sub-optimal health (OR 2.41 [1.05, 5.51]), compared to those with no history of sleep disturbance.

Sensitivity analyses of other possible confounders did not appreciably alter the main findings, with two exceptions (Table S3). Adding baseline depression attenuated the results for both genders (Table S3, Model 3), whereas a lower threshold of sleep disturbance amplified the results for young women (Table S3, Model 5). Our complete case analyses showed similar and stronger associations between chronic sleep disturbance and sub-optimal health for both young women (OR 2.89 [1.58, 5.27]) and young men (OR 3.12 [1.62, 6.03]) (Table S4, Model D). Estimates of covariables in main models are given in Tables S5 & S6. Analysis of clustering yielded similar results to complete cases without adjustment (Tables S7 & S8).

4. Discussion

This prospective study leveraged longitudinal data from BC's youth cohort to develop a measure of cumulative exposure to deficits in sleep quantity and quality over one year, and found young people were more vulnerable to sub-optimal health from cumulative exposure to sleep disturbance, independent of known confounders. Both young women and men reporting chronic sleep disturbance were over two times more likely to report non-excellent health than counterparts with no history, with stronger effects seen in young men. However, cumulative exposure to sleep deprivation showed no clear relationship with adolescents' health status. Findings were robust to several sensitivity analyses and were amplified when analysing only participants with complete information. Our results therefore supported only part of our hypothesis that prolonged deficits in sleep quality would be linked to sub-optimal health in a gender-specific manner.

Our mixed findings echo broader work on the relationship between shortened sleep duration, or sleep disturbance, and adolescent health (Holmström et al., 2014; Roberts et al., 2002; Kuo et al., 2014; Roberts et al., 2009). Our null findings for chronic sleep deprivation are consistent with previous studies showing no prospective association between shorter sleep duration and SRH in young people. Using longitudinal data from 4175 young people aged 11–17 in the Teen Health 2000 (TH2K) cohort, Roberts et al. (2009) found short sleep (≤ 6 h) was not linked to health one year later after adjusting for multiple confounders (Roberts et al., 2009). Sleep quantity was also not related to

Table 1
Descriptive analysis of sociodemographic and health characteristics of young people in the BASUS cohort across levels of cumulative sleep deprivation and disturbance.

	Female	Mean (SD) age	White ethnicity	Mean (SD) BMI	Post-pubertal stage	High family income	Mother's highest education	Existing health condition	Mean (SD) CESD score	Sub-optimal health
History of sleep deprivation										
None (n = 2228)	51%	14.8 (0.7)	54%	22.1 (4.3)	9%	41%	41%	52%	15.8 (10.8)	76%
Occasional (n = 531)	53%	14.8 (0.7)	49%	21.9 (4.3)	7%	36%	35%	51%	18.1 (11.3)	81%
Chronic (n = 345)	62%	14.8 (0.7)	37%	21.5 (4.0)	12%	34%	36%	58%	19.4 (11.5)	84%
History of sleep disturbance										
None (n = 497)	48%	14.7 (0.7)	43%	21.5 (4.0)	8%	48%	45%	42%	10.4 (8.2)	70%
Occasional (n = 727)	48%	14.8 (0.7)	49%	22.9 (4.4)	8%	42%	41%	51%	14.1 (9.5)	75%
Chronic (n = 1881)	56%	14.8 (0.7)	54%	22.1 (4.3)	9%	36%	37%	55%	19.2 (11.3)	81%

Percentages represent the proportion of participants having a given characteristic within each category of cumulative exposure (i.e. no history of sleep deprivation, occasional sleep deprivation and chronic sleep deprivation). Data on imputed sample (n = 3104) were from wave 4 for obesity, wave 5 for socio-demographic and health characteristics, and wave 7 for depression. BMI, body mass index (kg/m^2); high family income was perceived as far above average/quite a bit above average relative to peers; CESD, Centre for Epidemiologic Studies Depression Scale score (CESD score ≥ 24); health conditions reported over the past 12 months (ADD/ADHD, asthma, epilepsy, headaches, infection, painful menses, stomach issues).

Table 2
Odds ratios of sub-optimal health across levels of cumulative sleep deprivation in young women and men in the BASUS cohort.

	Model A		Model B		Model C		Model D	
	OR	CI95	OR	CI95	OR	CI95	OR	CI95
Young women*								
History of sleep deprivation								
None	Ref.		Ref.		Ref.		Ref.	
Occasional	1.94	0.87, 4.30	1.96	0.87, 4.38	1.95	0.87, 4.40	1.94	0.87, 4.31
Chronic	1.35	0.78, 2.35	1.38	0.78, 2.43	1.40	0.79, 2.48	1.36	0.76, 2.44
Young men†								
History of sleep deprivation								
None	Ref.		Ref.		Ref.		Ref.	
Occasional	1.27	0.81, 1.97	1.27	0.82, 1.98	1.26	0.81, 1.95	1.26	0.80, 1.98
Chronic	0.88	0.46, 1.66	0.91	0.48, 1.71	0.89	0.48, 1.65	0.88	0.48, 1.63

Gender-specific odds ratios (CI95) obtained from multivariable logistic regression analysis of imputed sample (N = 3104) using interaction terms between gender (*female = 0, male = 1; †male = 0, female = 1) and sleep deprivation (< 8 h/night) variables (Model A), sequentially adjusting for baseline BMI (Model B), ethnicity (White (reference), Asian, Aboriginal, or Other (Latino, Black, and Other)) (Model C) and family income as perceived relative to peers (far above average/quite a bit average (reference), slightly above, average, slightly below, quite a bit below/far below) (Model D).

Table 3
Odds ratios of sub-optimal health across levels of cumulative sleep disturbance in young women and men in the BASUS cohort.

	Model A		Model B		Model C		Model D	
	OR	CI95	OR	CI95	OR	CI95	OR	CI95
Young women*								
History of sleep disturbance								
None	Ref.		Ref.		Ref.		Ref.	
Occasional	1.21	0.69, 2.10	1.20	0.69, 2.09	1.20	0.70, 2.08	1.18	0.69, 2.02
Chronic	2.26	1.03, 4.94	2.20	1.01, 4.82	2.26	1.10, 4.63	2.18	1.13, 4.22
Young men†								
History of sleep disturbance								
None	Ref.		Ref.		Ref.		Ref.	
Occasional	1.53	0.82, 2.88	1.48	0.78, 2.80	1.49	0.81, 2.75	1.50	0.83, 2.72
Chronic	2.49	0.99, 6.24	2.42	0.96, 6.09	2.43	1.01, 5.85	2.41	1.05, 5.51

Gender-specific odds ratios (CI95) obtained from multivariable logistic regression analysis of imputed sample (N = 3104) using interaction terms between gender (*female = 0, male = 1; †male = 0, female = 1) and sleep disturbance variables (Model A), sequentially adjusting for baseline BMI (Model B), ethnicity (White (reference), Asian, Aboriginal, or Other (Latino, Black, and Other)) (Model C) and family income as perceived relative to peers (far above average/quite a bit average (reference), slightly above, average, slightly below, quite a bit below/far below) (Model D).

SRH after two years in a smaller study of Mexican-American older adolescents (Kuo et al., 2014). In both studies, sleep duration was measured once at baseline to predict health status a year or two later, hence neither longitudinal study captured the cumulative effect on adolescents' SRH of prolonged exposure to sleeping less than recommended amounts.

By contrast, there is consistent evidence of a relationship between sleep quality and SRH. Another prospective study using the TH2K cohort data examined extreme sleep disturbance (insomnia): adolescents were 86% more likely to report sub-optimal health a year later, after adjusting for baseline SRH and socio-demographics (Roberts et al., 2002). That study differs from this work because Roberts et al. (2002)

assessed the psychiatric disorder of insomnia using a composite score, and their analysis did not use longitudinal data to determine cumulative effects of insomnia. The link between good quality sleep and excellent health is also likely age- and gender-specific. A three-year Swedish study indicated that good quality sleep was concurrently linked to high SRH in females aged 10 to 13 years, but in males aged 13 to 16 years, and associations were stronger in young men (OR 2.6) than young women (OR 2.0) in those respective age groups (Holmström et al., 2014). That study also only analysed the concurrent effect of a single measure of sleep on SRH in different educational cohorts.

The finding that chronic sleep disturbance, and not chronic sleep deprivation, was associated with sub-optimal health warrants more research. The cumulative effect of having difficulty falling asleep or staying asleep may be more profoundly related to SRH than chronic sleep deprivation, or may precede it. The intermittent nature of sleep disturbances is known to have numerous adverse effects with implications for overall health and wellbeing, including increased stress responsiveness, poor diet, low physical activity, risk-taking behaviours, new or recurrent physical ailments, mental health issues, even poor school performance (Shochat et al., 2014; Medic et al., 2017; Luntamo et al., 2012; Lang et al., 2016). Thus, the profound impact on general health from chronic sleep disturbance can be attributed to the dynamic interplay of biological, psychological, social, and behavioural factors (Medic et al., 2017). Our study showed that mental health might be a mediator as depression as a covariable attenuated results, but other potential mediators to study might also include vitality (Craig et al., 2018). Future research should also assess whether reduced physical activity and/or diet quality—factors not measured in BASUS—mediate the link between chronic sleep disturbance and sub-optimal health. Moreover, it is quite likely that prolonged deficits in sleep quality lead to shortened sleep that in turn cause difficulty falling or staying asleep (Lovato and Gradisar, 2014). This negative feedback loop can exacerbate existing health conditions or induce new ones (e.g. depression, suicidality), and increase unhealthful behaviours (e.g. poor diet and nutrition, physical inactivity, excessive screen time) that together contribute to sub-optimal health (Shochat et al., 2014; Chaput et al., 2016; Craig et al., 2018; Lang et al., 2016; Lovato and Gradisar, 2014). New research should consider the relative importance and interactions of chronic sleep disturbance and chronic sleep deprivation which goes beyond the scope of this study.

Regular good quality sleep as an important determinant of young people's health has implications for future policy and programming. Sleep disturbances can be prevented by proper sleep hygiene practices that address different modifiable psychosocial and behavioural factors influencing sleep quality. Studies specifically show that late-night screen use and caffeine consumption have harmful consequences for falling sleep (Cain and Gradisar, 2010; Bartel et al., 2015). Young people's health may benefit from parental use of sleep schedules and restrictions on night-time electronic media use and electronic media in the bedroom (Cain and Gradisar, 2010; Bartel et al., 2015). Robust evidence for policy and interventions is needed on appropriate strategies to reduce young people's chronic exposure to poor quality sleep.

This longitudinal study has some limitations. Our self-reported exposures and outcomes could be limited by recall or social desirability bias, although our measures of potential bias indicated participants provided truthful responses. Moreover, SRH is established as a strong health measure as it predicts 14-year survival across socio-demographic groups in Canada (Falconer and Quesnel-Vallée, 2017). Measurement error of self-reported exposures and outcomes from large intra-individual variation or inaccurate instruments can either increase or decrease observed associations. But, while objective measurement would increase the validity of sleep measures, it would be impractical to implement in a large population-based cohort. There may also be measurement error in the self-reported times for going to sleep and waking up during the weekday, including missed information on time spent napping during the day; nevertheless, any misclassification of cumulative sleep deprivation from reporting bias would be non-differential as it was unlikely to be related to the outcome measure, and thus would have biased estimates towards the null.

Another source of bias is non-response from young people in lower socioeconomic positions or who dropped out of school as these youth may be more likely to experience regular sleep problems and have more health issues. Furthermore, our novel exposure categorizations do not account for the sequential timing of sleep deprivation or poor sleep despite the use of multiple measurement points of sleep to construct the cumulative exposure to sleep deprivation and disturbance (Waves 5, 6, and 7) prior to the measurement of SRH at follow-up (Wave 7). Results are also subject to residual confounding from factors that could be related to both exposure and outcome (e.g. physiologic stress levels) that were not collected in this particular study. The potential clustering of our data at the school level is likely to negatively bias/under-estimate our standard errors, however the estimated effect sizes will still be unbiased (Raudenbush and Bryk, 2001). Finally, our results from the province of British Columbia may not be generalizable to other provinces in Canada, or to other countries. Nonetheless, previous longitudinal studies conducted in the United States and Sweden have found similar findings (Holmström et al., 2014; Roberts et al., 2002; Kuo et al., 2014; Roberts et al., 2009).

Notwithstanding these limitations, findings are supported by several study strengths (Crowley et al., 2018): a longitudinal design with sufficient interval to assess prospective associations of chronic sleep deprivation and disturbance with SRH (Hirshkowitz et al., 2015); data collected from a large, diverse and representative sample of BC's adolescent population (Smith et al., 2014) (Paruthi et al., 2016); statistical control for several for key social determinants of health in our analyses; and (Chaput and Janssen, 2016) multiple imputation to minimize bias in overall estimates. The estimates from our multiple imputation were robust to alternative model specifications, replicated by our complete case analyses and consistent with the broader literature in this domain. Furthermore, this study adds novelty to the literature by developing a novel exposure variable examining the chronic nature of sleep deprivation and sleep disturbance. It also defined sleep deprivation according to age-specific guidelines based on scientific research and consensus (Hirshkowitz et al., 2015). Finally, the study fills a knowledge gap in how gender modifies the influence of chronic sleep deprivation on general health in young people.

In conclusion, sleep is an integral part of growth and development and young people are especially vulnerable to the health consequences of chronic sleep problems. This longitudinal prospective study underscores the importance of investigating different types and amounts of cumulative sleep problems and showed robust effects on SRH in young people. We found cumulative sleep disturbance, but not cumulative sleep deprivation, had a significant negative impact on the SRH of young people in BC, with stronger effects in young men. Future public health research on the health and wellbeing of young people should include measurement of both sleep quality and quantity in their assessments, and preventive strategies should consider promoting “a good night's” sleep as well as recommended a minimum number of hours of sleep.

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Competing interests

None declared.

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