Is the association between sleep and internalizing symptoms mediated by student and parent-related pressures?

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ABSTRACT

Objectives: Inadequate sleep has been afforded relatively little attention, despite known declines over adolescence, a critical period for the onset of mental ill-health. There remains a need for population-level longitudinal studies to better understand links with internalizing symptoms and in managing relevant pressures among adolescents. We examined the bidirectional relationships between sleep and depression and anxiety symptoms, and whether the relationships are mediated by school- and parent-related pressures.

Measures: We used 2-year linked prospective data from 25,722 Canadian secondary school students that participated in the COMPASS study in the 2017-18 and 2018-19 school years. Path analysis models tested autoregressive and cross-lagged relationships between sleep duration and depression and anxiety symptoms. Bootstrap method of indirect effects was used to test school and parent pressures as mediators.

Results: Results supported the hypothesized bi-directional relationships between sleep duration and depression and anxiety symptoms across one year. Shorter sleep predicted greater internalizing symptoms, and vice versa. In females, both parental and school pressures mediated the association between sleep duration and depression and anxiety symptoms, and in the reverse direction, parental but not school pressures mediated the association between depression and sleep. In males, school pressures mediated the association between sleep and depression symptoms.

Conclusions: This study provides new insights into the nature and directionality of associations between sleep and internalizing symptoms over time and differences by sex. Results further strengthen calls that short sleep should be taken seriously. Interventions promoting regular sleep schedules in adolescence may help mitigate risk for stress-related psychopathology.

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

Chapter 3

Chapter 4

Table 6. Pearson Correlations for Study Variables for Time 1 (2017-2018) and Time 2 (2018-2019) of the COMPASS Study.

Table 7. Fit statistics for autoregressive and cross-lagged models of sleep duration, student and parent pressures, and anxiety and depression symptoms among adolescents that participated in Years 6 and 7 of the COMPASS Study

Table 8. Standardized parameter estimates of autoregressive and cross-lagged associations between sleep duration, student and parent pressures, and anxiety and depression symptoms among adolescents that participated in Time 1 and Time 2 of the COMPASS Study.

Table 10. Standardized parameter estimates, stratified by sex, of the autoregressive and cross-lagged associations between sleep duration, student and parent pressures, and anxiety and depression symptoms, among adolescents that participated in Time 1 and Time 2 of the COMPASS Study.

LIST OF ABBREVIATIONS

COMPASS	Cannabis, Obesity, Mental Health, Physical Activity, Alcohol, Smoking, Sedentary Behaviour
Cq	COMPASS student questionnaire
ICC	Intraclass Coefficient
SD	Standard Deviation
CI	Confidence Interval
GAD-7	Generalized Anxiety Disorder 7 Item Scale
CESD-R-10	Centre for Epidemiologic Studies Depression Scale 10-item Revised Scale

Introduction

The role of sleep duration in youth mental ill-health has been largely overlooked at the population level (1,2). Most mental disorders have their onset during adolescence, a time when sleep durations typically decline (3). In representative Canadian surveys, about one-third of Canadian children and adolescents report sleeping less than the recommended amount (4,5). In national US data, over 60% of ninth-grade high school students are not sleeping the recommended eight hours per night, and this rate increases over the course of high school (3). Although the ideal amount of sleep may vary from one person to another, sleep duration recommendations are important for promoting health by informing the population of beneficial sleep behaviours (5,6). The Canadian 24-hour Movement Guidelines were developed with the hopes of improving health outcomes in children and youth (7). However, the global prevalence of children meeting the overall health recommendations is 7%, with children from Canada and Australia showing the highest percentage of adherence, which is only 14% and 15%, respectively (7). An 18-member multidisciplinary expert panel, comprised of sleep researchers, physicians, and experts in other areas of medicine, recommend that adolescents aged 14-17 years should get an average of 8-10 hours of uninterrupted sleep per day (5,6,8). For this particular age group, overall health, wellbeing, emotional and physical health were taken into account when voting on appropriate sleep for this age group (6). Therefore, sleep durations that are far outside the normal range should raise concern (6).

Shorter sleep duration during adolescence has been associated with depressed mood, reduced motivation and cognitive functioning, and behavioral and physical health problems (9–12); whereas, adequate sleep, both in quantity and quality, is shown to improve adolescents' cognitive functioning, alertness, and energy throughout the day (13–15). It has been found that

even after a single night of restricted sleep, higher cognitive functions such as verbal creativity and abstract thinking are restricted, even after routine performance is maintained (16). While many cross-sectional studies support associations between lack of sleep and emotional and behavioral difficulties in adolescence (17,18), studies using prospective designs and large population samples of Canadian children and adolescents are lacking. Further longitudinal research is required to understand the complex interplay between sleep and mental health, to better inform interventions and prevention efforts for mental ill-health.

Adequate sleep may help youth manage stress, and in turn, prevent internalizing symptoms (12). Adolescents are facing increasing academic demands, all while being expected to cope in increasingly complex situations (19). When these demands are perceived as excessive, they can result in decreased motivation, increased distress, and elevated school burnout (20). It has been found that increased stress from this environment and the learning pressures they generate may influence sleep among adolescents (21,22). Thus, maintaining a positive academic life for a successful future represents a key stressor during adolescence (23). In a Canadian sample, 70% of students that had less than an 8.5 hour weeknight sleep were more likely to feel that their grades had dropped due to sleepiness, and often felt sleepier at school (24). Additionally, cross-sectional evidence suggests perceptions of school-related pressures and demands are strongly correlated with anxiety among older adolescents (25). A recent study including over 900,000 adolescents from 36 countries participating in the Health Behaviour in School-aged Children (HBSC) surveys found students' perceptions of school pressures have increased over the last 16 years (26). In a cross-sectional Swedish study of 16-18-year-old students, high pressure and demands from school were experienced by 63.6% of girls and 38.5% of boys, and were correlated with health complaints and anxiety (25). Girls perceived stress and

reported health complaints two to three times more frequently than boys, including headaches, tiredness and sleeping difficulties, as well as sadness and anxiety (26). This finding is consistent with a more dated study, as perceptions of school pressures and reported internalizing symptoms are generally higher among girls (27). In addition to gender, the impact of academic stress on youth appears to vary by parental relationships and other sociocultural influences. Wolfson and Carskadon proposed the relevant role of environmental and family influences, especially when comparing students from different schools and different families (10). At the high-school level, a study has found that the level of academic expectations for students (both self-expectations and parent expectations) is positively related to good academic achievement (28). In regard to sociocultural influences, it has been found that the closer the parent-adolescent relationship, the greater the intensity of adolescents' academic stress experienced in Korean cultures (29). In contrast, in Western countries, positive parent-adolescent relationships were found to predict reduced academic stress (30).

Promoting adequate sleep among youth may prove as an effective strategy to help youth manage school and parent related pressures and for the prevention of mental illness at this critical developmental period. Building on existing research, my thesis will examine the prospective associations between sleep duration and mental ill-health (i.e., depression and anxiety) in a large cohort of high school students across Canada. Specifically, the purpose of this study is to examine the role of sleep in managing relevant stressors to youth and preventing internalizing symptoms. Relationships will also be explored by gender, given evidence of varying sociocultural influences on parental relationships, academic expectations, sleep, and internalizing symptoms (2–5,12,31,32). Using linked student data from Year 6 (2017-2018) and Year 7 (2018-2019) of the Cannabis, Obesity, Mental health, Physical activity, Alcohol,

Smoking, and Sedentary behaviour (COMPASS) study (herein referred to as COMPASS), the following research questions will be addressed:

RQ1) How are changes in sleep duration associated with changes in depression and anxiety over a one-year period?

Hypothesis: There will be significant bi-directional relationships between sleep duration and depression and anxiety symptoms. In other words, sleep duration at baseline will predict depression and anxiety symptoms one-year later, and depression and anxiety symptoms at baseline will predict sleep duration one-year later (i.e., less sleep associated with more psychopathology and vice-versa).

RQ2) Is the relationship between sleep and depression and anxiety symptoms mediated by student pressures (school-related and/or perceived parental pressures)?

Hypothesis: The relationship between sleep and depression and anxiety symptoms will be mediated by student pressures and/or parental pressures. Specifically, shorter sleep duration will be associated with higher perceived student and parent pressures, which in turn, will be associated with greater depression and anxiety; and in the reverse direction, higher depression and anxiety will be associated with higher perceived student and parent pressures, which, in turn, will be associated with shorter sleep duration.

2.1 Literature Review

2.2.1 Youth Sleep Trends

Insufficient sleep has become common in recent times with studies showing declines in sleep duration and more sleep problems and tiredness now compared with previous decades in children and adolescents (33). Inadequate sleep has been recognized as one of the leading public

health concerns in adolescents worldwide (34), given its prevalence and implications in a wide range of physical and mental health conditions (32,35). Authors suggested that sleep problems, or short sleep duration, may negatively impact cognition and instead bring forward poor judgement, deficits in impulse control, tiredness, and hopelessness (36). Along with well-defined sleep disorders, major sleep difficulties are included in the diagnostic criteria for major depression, bipolar disorder and major anxiety disorder (15). Generally, insufficient sleep has been linked to increased risk of mood disorders, inattention, poor grades, behaviour problems, substance use, and obesity and diabetes; whereas, youth getting sufficient sleep demonstrate improved concentration and alertness, emotion regulation, learning, memory, and physical and mental health (2–5,9,37,38). However, research on the role of sleep in mental health has predominantly focused on sleep disorders in clinical samples or been limited to cross-sectional designs. A recent longitudinal Canadian study of grade 9-12 students found continued adherence to sleep guidelines, and changes from insufficient to sufficient sleep, over a one-year period were associated with lower depressive symptoms in youth, relative to continued nonadherence (39). It has been speculated that adequate sleep duration and quality of sleep may be beneficial for reducing the risk of developing emotional and behavioural problems in adolescents (40).

Sleep plays a crucial role in healthy adolescent development (4); yet several psychosocial and biological changes during adolescence can limit sleep (37). In addition to reduced parental monitoring, heightened school pressures, and extracurricular and social activities, a natural circadian shift towards delayed sleep onset occurs at puberty, which contributes to the later bedtimes in adolescents (37). Delayed bedtimes contribute to declines in sleep with increasing age over adolescence; adolescents go to bed later, but early school start times prohibit sleeping in (37). As a result, many adolescents try to “catch up” by sleeping longer on weekends, referred to

as social jet lag (41). According to the US Longitudinal Study of Adolescent Health, sleep durations decrease across the adolescent period from an average of 8.5 hours per night at age 13 to 7.3 hours at age 18, followed by increases through the emerging adulthood period to 8.5 hours at age 22 (42). In Canadian data, more adolescents are short sleepers, report sleep problems and tiredness during the day, and sleep 1.4 hours less on average than children (5).

According to the Canadian 24-Hour Movement Guidelines, youth aged 14–17 years old are advised to get an uninterrupted 8 to 10 hours of sleep per night with consistent sleep and wake times to promote optimal health (8,38). For those not currently meeting these guidelines, a progressive adjustment toward them is recommended (8). In the Canadian Health Behaviour in School-aged Children (HBSC) study, 26% of adolescents aged 14 to 17 years old reported sleeping less than the recommended amount (4). Similarly, in the Canadian Health Measures Survey (CHMS), 29.8% of adolescents were short sleepers and 2.4% exceeded recommendations (5). Some evidence suggests sleep durations have gradually declined over the past few decades. Dollman and colleagues (43) noted a 30-minute decline between the years 1985 and 2004 for 10-15 year-old Australian children on school nights, while a systematic review by Matricianni and colleagues indicated a decline of 0.75 min per year from 1905 to 2008 in children's sleep durations using data from 20 different countries (33). In a more recent Canadian study, average sleep durations declined over 3 years, resulting in less than half of youth meeting the guideline of 8-10 hours per night (44). This particular study also found that longer sleep durations occurred in students who identified as male, white, in earlier grades, and attended schools in areas with higher median household income (44).

Other research also suggests variations in sleep durations by ethnicity, socioeconomic status (SES), and gender. For instance, shorter sleep durations were most common in African

American adolescents and young adults in a representative US study (42). Asian adolescents tend to go to bed later than their North American counterparts, and as a result, generally obtain less sleep (45). Furthermore, in Canadian studies, shorter and poorer quality of sleep was more common in lower socioeconomic groups; and in fact, has been suggested to contribute to health inequities (44,46). Evidence of sex and gender differences in sleep is mixed. For example, one study found that boys reported later weekday and earlier weekend wakeup times than girls (47). Oginska and Pokorski demonstrated that females in high school (aged 14 to 16 years) required more sleep time than males, and exhibited a higher level of daytime sleepiness (48). However, no gender differences in adolescent sleep patterns were found in another study using objective measures (49).

2.2.2 Youth Mental Health and Depression/Anxiety

Poor mental health and mental illness in adolescence can have a lasting impact on later adult mental and physical health, academic achievement, and relationship and work satisfaction (50). Over three quarters of youth with a mental illness had their first onset between the ages of 11 and 18 (51). Additionally, approximately one in every 4-5 adolescents will meet criteria for a mental disorder with severe impairment in their lifetime (52). In a representative Canadian sample, symptoms of poor mental health in children and adolescents between the ages of 10 to 15 years remained relatively stable over a 15-year time point (1994-95 through 2008-09), with the exception of hyperactivity (53). Hence, improved strategies are necessary for the prevention and early invention of mental illness among youth.

Anxiety and depression are among the most frequently occurring mental illnesses among adolescents (52) and contributing to significant impairment in multiple domains, including academic functioning, peer and family relationships, substance use, and later adult

psychopathology (51–56). However, symptoms often go unnoticed and many individuals do not seek support (51). Based on nationally representative sample of US adolescents, 32% and 14% of 13-to-18-year olds met criteria for an anxiety disorder and mood disorder, respectively (52). Symptoms of anxiety and depression occur more frequently in girls relative to boys (55). Girls tend to report more internalizing symptoms or emotional problems, while boys have more externalizing symptoms or behavioural problems (51).

Anxiety and depression symptoms are also frequently comorbid. An estimated 25–50% of youth with depression have comorbid anxiety disorders and about 10–15% of youth with anxiety disorders have depression (54). Anxiety typically predates depression (57,58), leading researchers to suggest that anxiety may be a vulnerability factor for developing subsequent depression (59). There is a recent belief that depression, or major depressive episodes, are increasing in adolescence; however one longitudinal Canadian study showed that the prevalence did not significantly change in the adolescent population between 2000 and 2014 (60). In fact, the findings of this research suggest past year depression symptom prevalence has not changed significantly for Canadian adolescents over the last 15 years (60). Longitudinal studies also have shown that anxiety predicts increased levels of depressive symptoms over time (58). Additionally, depressive symptoms predicted subsequent elevations in anxiety symptoms among children who had mothers with a history of anxiety or reported a low family relationship quality (55).

2.2.3 Biological Processes on Sleep and Depression/ Anxiety Symptoms

Adolescence is hallmarked by dramatic maturational changes in sleep and its neurobiological regulation, hormonal status, and physical processes. During adolescence, sleep is a vital process that is linked to physiological maintenance across multiple domains. For instance,

it has been proposed that sleep plays a critical role in brain development, as well as emotional, cognitive and behavioural self-regulation (15). It is therefore essential that researchers understand the biological processes associated with sleep functioning, as well as the impact of shorter sleep durations.

Studies have shown that REM sleep latency at night is generally shorter in adolescents than in prepubertal children; children experience larger amounts of deep slow-wave sleep, which gradually decreases as they progress into adolescence (37,61). As well, higher cortical brain functions are active and resemble wakefulness during this stage (15). However, studies of impaired REM sleep regulation during development in both males and females exhibit more risk factors, depression, and elevated responses for stress and anxiety (63).

The timing of sleep onset, the length of sleep, and the timing of REM sleep vary as a function of the phase of the circadian timing system (15). Weekend sleep for adolescents tends to delay further, and the difference in amount of sleep reported for school days versus weekends becomes more pronounced as children pass into higher grades (i.e., greater reported sleep on weeknights than school nights) (61). The circadian timing may depend on an underlying biological change that is then affected by behavioral exposures that arise during adolescence (i.e., staying awake later, thus experiencing more evening light). A converse to this hypothesis is that adolescents become less sensitive to phase advancing (morning) light. This circadian system is involved not only in the timing of sleep but also the timing of brain hormone release and body temperature regulation (61). The signal from the brain's central clock is thought to affect sleep and arousal systems to help gate the timing of sleep (61).

Both community-based and clinical research suggests that short sleep is associated with increased levels of anxiety and depression in both children and adolescents (37,64,65). In fact,

risk of developing an anxiety or depressive disorder is significantly higher among adolescents with insomnia than the general population (64).

Short sleep durations may cause an increase in cortisol levels (64,66–69). the hypothalamic–pituitary– adrenocortical (HPA) axis, which regulates the release of cortisol, is the biological system most closely tied to the experience of stress or elevated anxiety symptoms (66). Generally speaking, cortisol is an important hormone associated with psychological and physical health functioning, and may reflect greater physiological reactivity to stress that prevent both children and adolescents from getting adequate sleep (67). Cortisol levels tends to follow a pattern in which they peak shortly after waking and then decrease throughout the day, reaching their lowest point around midnight before beginning to rise again (66). However, one study found that children with increased sleep disruptions evidenced in shorter sleep duration and poorer sleep quality, had higher levels of afternoon cortisol (66). Furthermore, elevated levels of daytime cortisol are associated with worsened mental-ill health, and have been shown to cause problems with learning and memory (66). Additionally, overactivation of the HPA axis may represent maladaptive coping to stress that predicts sleep disruptions (66). In clinical samples, both children and adolescents with anxiety disorders have been observed to have elevated cortisol levels around sleep onset (68,70).

2.2.4 Academic Stress and Parental Expectations

Academic pressures are a major cause of adolescent stress (27) and have increased over recent years (26). Academic stress is defined in the literature as subjective stress that involves frustration associated with academic failure, the feeling of failure, or even an awareness of the possibility of such failure (72). School pressure is a complicated, but real issue that affects many children in varying degrees and at different times throughout the course of their education (73). It

is speculated that as children progress through the educational system, they are subjected to greater academic demands and expectations (73). School pressure seems to increase alongside the onset of adolescence and the shift from elementary school to the higher demands and expectations of secondary education (52). School grades are a primary concern at the secondary school level for many students, educators, and parents; not only as an indicator of academic performance, but also as a determinant for acceptance to post-secondary education (26). Globally, children in North America reported the highest levels of school pressure (74).

A large proportion of both girls and boys reported health complaints and perceived stress at the secondary level (25). High pressure and demands from school were experienced by 63.6% of girls and 38.5% of boys (25). However, evidence is mixed on gender differences among secondary students in terms of whether females or males perceive more academic stress (75,76). High academic stress is detrimental to adolescent academic performance, adaptation, and general health (72). In a recent study on adolescents aged 13 to 18 years old, nearly 10% of students reported that they did not handle school-related stress well (77). Their perceptions of how their support group viewed their academic performance, concurrently with having jobs while going to school, and fear of theft of personal belongings, were identified by students as being the stressors of greatest concern related to school (27,77). In a US study, school-related stress independently and in interaction with high academic expectations negatively affected academic performance in adolescence even three years later (19). High-stress school environments, paired with an increase in academic expectations, may serve to increase school-related stress and impede academic performance (19).

Previous research suggests sociocultural variations in perceived academic stress, parental relationships, adolescent sleep, and their interrelationships. The central finding in a Korean study

was that the closer the parent-adolescent relationship, the greater the intensity of adolescents' academic stress (29). Chinese adolescents have been found to suffer from more chronic sleep difficulties than their Western counterparts, due to the high level of academic pressure from school staff and parents (78). In contrast, positive parent-adolescent relationships predict reduced academic stress in Western countries (30). That said, almost half of US secondary school students agreed that their parents do not care how much sleep they get, as long as they achieve good grades (79). These rising expectations can result in increased pressure to succeed in school, with the potential to have either positive or negative impacts on young peoples' learning, health and emotional well-being (80). Excessive pressure or stress may negatively impact students' academic performance, as well as their physical health, emotional well-being, and mental health. That being said, a growing body of research indicates that supportive communication can improve outcomes for stressed individuals (84). Thus, it is worthwhile to consider the role of parental relationships when discussing academic pressures that young students may face, as it is clear it may be a critical component in the academic context.

2.2.4 Sleep in Relation to Academic Stress and Mental Health Symptoms

While past studies have demonstrated youth's awareness of the 8–10 hours of sleep recommended for their age group, the links between insufficient sleep and overall health appear poorly understood (6). Though results vary by age, both anxiety and depressive symptoms show an association with sleep problems among adolescents (64). Some evidence suggests that sleep duration and mental health status have a bidirectional relationship in adolescence (76). In clinical samples, sleep disturbance and mental illness have a bidirectional relationship (40). However, a more recent study found that while short sleep duration at baseline predicted anxiety disorders

two years later, anxiety disorders at baseline did not predict short sleep duration at follow-up (85). In a Canadian study in a nonclinical sample, continued adherence to sleep guidelines and transitioning from inadequate to sufficient sleep over a one-year period was associated with lower depressive symptoms, relative to continued nonadherence (39).Adolescents with depression are also shown to experience significantly more wakefulness in bed, lighter sleep, and report more subjective sleep disturbance (86).

A growing body of research proposes that relationships between sleep and risk of poor mental health or mental illness may be rooted in disrupted emotion regulation (i.e., the ability to control or modulate one's emotions) (87). Adolescents who report greater sleep problems are more likely to have a mood or anxiety disorders, and generally report poorer emotion regulation strategy use, even when accounting for current stress (89). Adolescence is characterized by higher risk for the development of mental illness than previous points in development, and stressful events become more closely linked to the emergence of negative affect during this period, rendering adolescents more emotionally vulnerable to the effects of stress (90,91).

Short sleep durations in adolescence are an important public health issue, as they are a threat to the academic success and overall health of youth (12). Some studies have addressed severe stress-related disorders of school-burnout and chronic stress among older adolescents (94). For example, one study found that the stress of school performance was positively related to depressive symptoms and inversely related to life satisfaction (95). Moreover, students in high school who described themselves as struggling or failing school reported that on school nights, they obtain about 25 minutes less sleep and go to bed an average of 40 minutes later than students achieving A and B grades (10). In order inform effective strategies to promote mental health and prevent mental-ill health in adolescents, it is important to better understand the

association between adequate sleep, student pressures, and mental health status at the population level.

Other past research found that sleeping directly after learning improves memory consolidation and might contribute to better academic functioning (11). A cross-sectional study investigated the relationship between negative affect, worry, working memory, and academic performance using self-report questionnaires, school administered academic test data, and a battery of computerized working memory tasks (96). The authors concluded that higher levels of anxiety and depression were associated with lower academic performance in children aged 12 to 13 years old (96). They had also found that worry and central executive processes mediated the relationship between negative affect and academic performance (96). Another prospective Canadian youth study found factors that contribute to reduced sleep in youth included cyber bullying, binge drinking, and spending more time doing homework (97). Overall, findings highlight the need for prospective research to establish the temporality of associations between academic stressors, sleep, and mental health status, to inform interventions for stress management and mental illness prevention in adolescents.

Chapter 3

3.1 Introduction

Inadequate sleep is common among youth, potentially impacting mental health outcomes. Existing research has highlighted the importance of sleep in clinical populations, in terms of the management of mental illness symptoms, and the impact of mental illness on sleep, but more research needs to be done at the population level using prospective data. There is a recognized need to examine sleep in a large-scale longitudinal design to further understand the links with depression and anxiety symptoms, and its role in managing stressors among youth populations

(98). The current study examined the role of sleep in managing relevant stressors to youth and preventing anxiety and depression symptoms. These relationships (RQ1 and RQ2) were examined for differences by gender, given literature demonstrating sociocultural variations in sleep, parent-child relationships, academic pressures, and emotional expression.

3.2 Methods

3.2.1 Design and Participants

This study used data from the COMPASS study, which is an ongoing (started in 2012) study designed to collect longitudinal and hierarchical data from students in grades 9 through 12 and the secondary schools they attend. The COMPASS student questionnaire (Cq) is a self-report paper-and-pencil survey completed once annually by full school samples during one classroom period (approximately 45 minutes) (99). The Cq collects student-level data on various health behaviours, outcomes, and correlates, including physical activity, sedentary behaviour, sleep, eating behaviours, substance use, mental health, bullying, academic achievement, school connectedness, and sociodemographic variables.

The current study used data from students successfully linked for Year 6 (2017-2018) and Year 7 (2018-2019) of the COMPASS study. Year 6 and Year 7 will be herein referred to as Time 1 (T1) (baseline) and Time 2 (T2) (one-year follow-up). These two years were selected as the first waves in which the mental health measures were completed by students attending all participating COMPASS schools (100).

Schools and school boards were purposely selected based on whether they permitted active-information passive-consent protocols, which are critical for collecting robust data among youth (101) and minimizing school burden. Inclusion criteria at the school-level included being a

secondary school with students in grades 9 to 12 with a student population of at least 100 students or more per grade that permits the use of active-information passive-consent parental permission protocols (102). COMPASS also measures school-level programs, policies, and built environment resources, and provides each participating school with a school-specific annual feedback report that highlights the school-specific prevalence for each outcome measured by COMPASS, while also providing evidence-based and context appropriate suggestions for school-based interventions designed to address the outcomes covered in the feedback report (102).

COMPASS has received approval from the University of Waterloo Human Ethics Committee, the Brock University Research Ethics Board, and all participating school boards. A full description of the COMPASS design and methods is available in print (99) and online (41).

3.2.2 Measures

Sleep duration. Consistent with previous studies using COMPASS data (39,44,97), sleep duration was assessed with the question on the Cq survey: "How much time per day do you usually spend doing the following activities: sleeping?" The provided response options include 0-9 hours and 15-minute intervals and were be coded as continuous variables.

Student pressures. Student pressures were assessed asking questions on the Cq survey related to homework time, student perceptions of the importance of good grades, academic aspirations, and perceived parental expectations. To assess homework time, students were asked: "How much time per day do you usually spend doing the following activities: homework?", with the provided response options of 0-9 hours and 15-minute intervals. The perceived value of good grades was assessed by asking students: "How strongly do you agree or disagree with the following

statement ‘Getting good grades is important to me.’” Response options included: Strongly agree, Agree, Disagree, and Strongly Disagree. Higher scores reflect greater student pressures. Perceived parental expectations were assessed by the item “my parents expect too much of me” with five response options ranging from Strongly Agree to Strongly Disagree. Higher scores reflect greater parent expectations. Finally, academic aspirations were assessed by asking students: “What is the highest level of education you would like to get? (Choose only one)” with the response options: Some high school or less, High school diploma or graduation equivalency, College/trade/vocational certificate, University Bachelor's degree, University Master's / PhD / law school / medical school / teachers' college degree, or I don't know. Higher scores reflect greater academic aspirations for this measure.

Mental ill-health: *Anxiety symptoms* were assessed using the Generalized Anxiety Disorder 7-item Scale (GAD-7) as a measure of self-reported anxiety (100). For the GAD-7, students were asked seven questions pertaining to the frequency of anxiety symptoms they have experienced in the last 2 weeks, such as uncontrollable worrying, irritability, and trouble relaxing. Students responded to each of the seven items on a 4-point Likert scale (0 = not at all, 3 = nearly every day). Items were summed to create a total score, with possible scores ranging between 0 and 21. Higher scores indicate greater impairment from generalized anxiety symptoms (103). The GAD-7 has shown good reliability, as well as criterion, construct, factorial, and procedural validity in adolescent populations (103). The internal consistency in the current sample at Time 1 was $\alpha = 0.90$ and Time 2 was $\alpha = 0.91$.

Depression symptoms were assessed using the Centre for Epidemiologic Studies Depression Scale (Revised)-10 (CESD-R-10), as a measure of self-reported unipolar depression symptoms (104). The CESD-R-10 assesses past-week depression symptoms (e.g., feelings of sadness,

loneliness, trouble concentrating, anhedonia and amotivation) using a 4-point Likert scale (0 = none or less than 1 day, 3 = 5– 7 days). Items were summed to create a total score between 0 to 30, with higher scores indicating greater depressive symptoms and risk of clinical depression (80). The scale was found to have very high internal consistency, construct validity and adequate test-retest reliability in asolescent populations (105). The internal consistency of the scores in the current sample at baseline was $\alpha = 0.72$ (Time 1), and in Time 2 the internal consistency of the scores was $\alpha = 0.73$. Both the GAD-7 and CESD-R-10 have demonstrated measurement invariance by sex and grade in the COMPASS study (106).

***Covariates and Confounders*.** Participant were asked to report their sex from two provided response options (male, female). Participant-reported grade (9, 10, 11, 12, other [Secondary I-II in Quebec]) and race/ethnicity (White, Black, Asian, Latin American/Hispanic, and Other/mixed [including students indicating other, more than one response, and First Nations, Métis, or Inuit) were included in the model. Ethics restrictions precluded the identification of students with Indigenous heritage for separate study. Student weekly spending/saving money ($0, $1-$20, $21-$100, more than $100, I don't know) from allowance or part-time employment was included as an proxy of student-level SES, in the absence of parental SES indicators in the waves used from the COMPASS study. Based on evidence of associations with sleep and/or mental health, other predictors were included in the model, such as student-reported substance use (40,107) and physical activity levels as previously used in COMPASS studies (108,109). Using a previously validated measure of moderate to vigorous physical activity (MVPA) (110), two items were used to assess how many hours (0–4) and minutes (0, 15, 30, 45) of "hard" and "moderate" physical activity the students did on each of the last 7 days (Monday-Sunday). School-level covariates included province (Ontario, Alberta, Quebec, British Columbia), and school-area median

household income (using data from the 2016 Census on census divisions that corresponded with school postal codes) (111).

3.3 Statistical Analysis

3.3.1 Preliminary Analysis

First, descriptive analyses were conducted in the SPSS Program (Version 28) to examine the frequency and distribution of variables. Second, correlations were examined among all study variables in both waves. A factor analysis was conducted for the items assessing "student pressures" to determine the appropriateness of forming a sum score or latent variable to represent student pressures or for use of items individually in the models, as parental expectations may be a separate, but related construct. Cronbach's alpha was calculated to examine internal consistency of the items forming a sum score. Missing data was examined to determine the appropriateness of a complete case analysis or estimation method (e.g. full maximum likelihood procedure). As power is not a concern given the large sample, the likelihood of missingness introducing bias will be explored.

Missing data were estimated using the full information maximum likelihood (FIML) estimation method (112). FIML retains cases that are missing survey waves, thus avoiding the biased parameter estimates that can occur with pairwise or listwise deletion (112). We eliminated those students who reported anything less than three hours of sleep (n = 1,179; 4.1% of the sample) resulting in a final sample of 25,722 students. As per a previous study on sleep (113), reports less than three hours of sleep were deemed as improbable responses or misreports. For the current study, at baseline, 3,269 students (5.7% of the sample) answered that they had less than three hours of sleep before data cleaning and 1,840 students (3.2% of the sample) answered

that they had zero hours of sleep. Outlier values for all other variables were Winsorized by setting extreme values at three standard deviations from the mean (114). In our sample, 19.3% of the sample (4,975 of students in Time 1) and 15% (3,857 students in Time 2) answered "I don't know" on the academic aspirations component of student pressures. For student pressures, a principal components analysis (PCA) was conducted on the four items representing the perceived value of good grades, homework time, academic aspirations, and parent expectations to inform how to combine the variables into a smaller number of components (115). In the analysis procedure of the PCA, the existence of hypothetical underlying factors is not necessary, and the component is simply a combination of correlated variables (115). PCA is one the most effective and widely used dimensionality-reduction techniques and is used by almost all scientific disciplines (116,117).

3.3.2 Primary Analysis

Two path analysis models (RQ1, RQ2) were performed to test the cross-lagged relationships between responses to self-reported sleep duration and depression and anxiety symptoms between the two assessment points separated by one year. Panel data analysis is a statistical method widely used in social and behavioural sciences to analyze two-dimensional data (114). Models test both cross-sectional and prospective relationships between variables. A cross-lagged model, a type of panel model, makes use of longitudinal data to infer underlying processes of reciprocal causality among the set of constructs and works well with larger sample sizes (118,119). Cross-lagged panel models were used to allow for the investigation of reciprocal relations between two variables over time and the identification of which variable is a more robust predictor (i.e., whether sleep predicts depression and anxiety symptoms, or vice versa).

For RQ1 (How are changes in sleep duration associated with changes in depression and anxiety over a one-year period?), a cross-lagged panel model was used to assess directionality using the Mplus Program (Version 8) (120). In the model, T1 constructs of sleep duration and depression/anxiety symptoms were tested as predictors of these same constructs assessed at T2. One model was tested for RQ1; as depression and anxiety are separate, but related constructs.

For RQ2 (Is the relationship between sleep and depression and anxiety symptoms mediated by student pressures [school-related and/or perceived parental pressures?]), a cross-lagged panel mediation model was conducted to test whether sleep duration (the independent variable) had an indirect association with depression and anxiety (the dependent variables) via student pressures (proposed intervening mediator). Most applications of mediation models are based on cross-sectional designs (121). However, researchers have argued against the practice of cross-sectional meditation analysis (122). With longitudinal panel designs, the most popular model for mediation analysis is the cross-lagged panel model (123). Fitting a cross-lagged panel model for longitudinal mediation typically requires at least three waves of data; when running analyses with two waves of data, it is called a half-longitudinal design (124). Mediation seeks to identify the effect of an independent variable (X) on a dependent variable (Y) via the inclusion of a third variable referred to as a mediator (M) (125). A mediation effect refers to a situation when the relationship between a predictor variable and an outcome variable can be explained by their relationship to a third variable: the mediator (Figure 1). When mediation occurs, the total effect of X on Y is partitioned into two components: the indirect effect of X on Y through M, and the direct effect of X on Y that cannot be explained by the indirect effect (usually denoted by c') (125). It is generally accepted that an analysis should be done regardless if there is a direct effect or not (126). Prior levels of M or Y are confounding variables that should be controlled when

testing the indirect effect and direct effect to eliminate bias in parameter estimates in mediation analysis (124). MacKinnon and colleagues (123) suggest using the bootstrap method to define the confidence intervals for mediation effects (127).

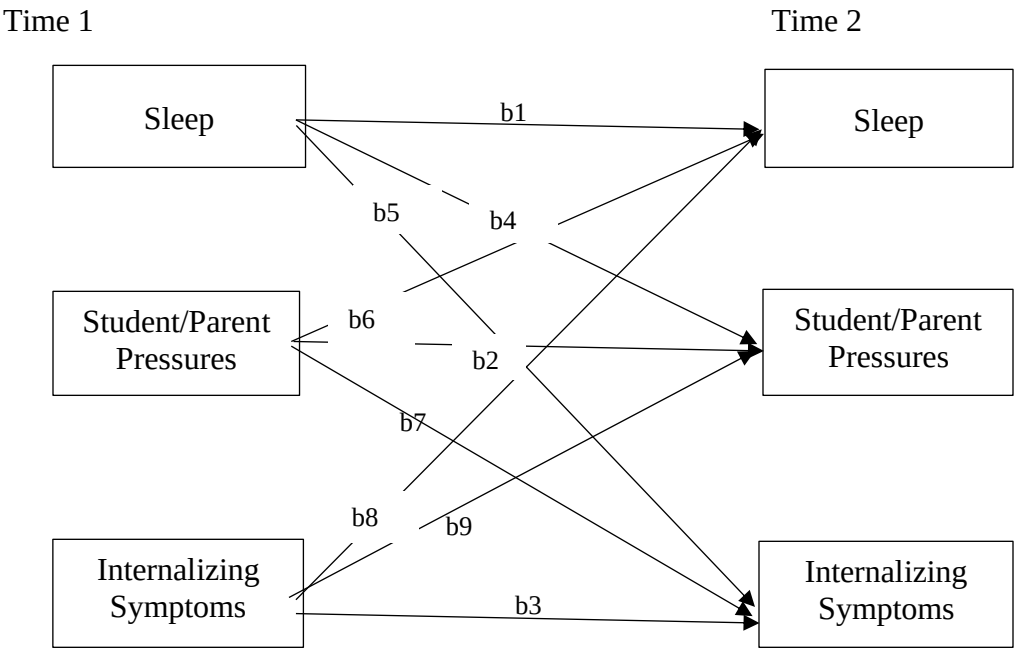


Figure 1. Structural diagram depicting associations tested between sleep, pressures (including both student [self-reported homework time, importance of getting good grades, academic aspirations] and parent pressures [parental high expectations]) and internalizing symptoms (which included anxiety [GAD-7] and depression [CESD-R-10] symptom scores), among adolescents who participated in Time 1 and Time 2 of the COMPASS Study in Alberta, British Columbia, Ontario, and Quebec.

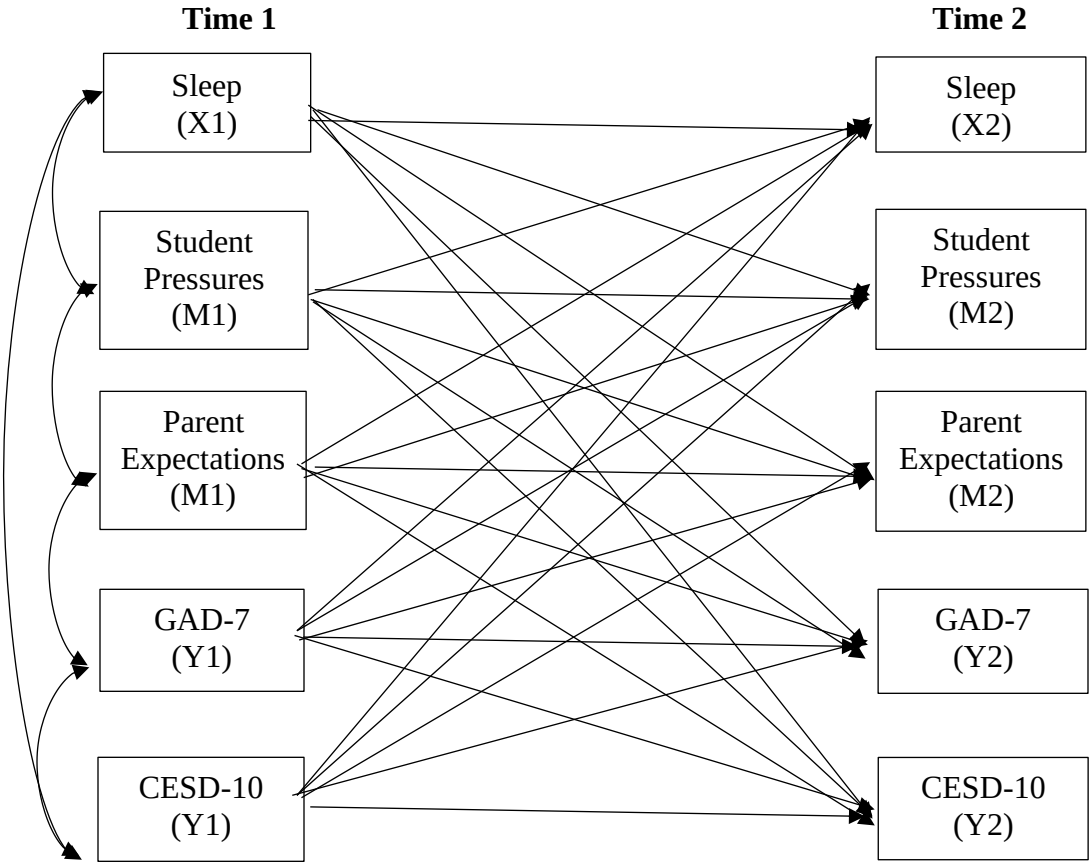


Figure 2. A conceptual model for a bi-directional cross-lagged panel mediation model testing whether sleep duration is indirectly associated with depression and anxiety via student pressures and parent pressures among adolescents that participated in Time 1 and Time 2 of the COMPASS Study.

For both RQ1 and RQ2, a random intercept at the school level was added to models to adjust for school clustering. As suggested by Simmons et al., (97) the models were first run without covariates, and then controlling for covariates measured at T1 (physical activity,

substance use, grade, weekly spending money, province, and school area median household income).

The main statistical analyses were conducted using path analysis in Mplus version 8.5. Criteria for model fit was based on the Comparative Fit Index (CFI), the Tucker-Lewis Index (TLI) and the Root Mean Squared Error of Approximation (RMSEA), such that CFI and TLI values greater than .95 and a RMSEA value of less than .06 indicated good fit (128,129). The analyses were based on two separate path models. The first model examined a cross-lagged panel model between sleep duration and depression and anxiety symptoms at Time 1 (2017-2018 school year), as well as predicting these same constructs at Time 2 (2018-2019 school year). All models adjusted for confounding variables (grade, weekly-spending money, physical activity, substance use, and ethnicity) and school-level clustering. The intra-class correlation (ICC) was calculated to measure the extent to which students within a cluster (i.e., schools) were more alike than those in different schools. The ICC indicated that 3.8% of the variance in sleep duration at Time 1, and 3.6% at Time 2, were explained by characteristics at the school level. Models were conducted for the full sample and stratified by sex to look at differences in fit and pathways between males and females.

For the second model, the Bootstrap method of indirect effects was used to test the mediating role of student pressures, as well as parent pressures. Mackinnon et al. (130) suggest using the bootstrap method to define the confidence limit intervals. It was examined whether there was a significant indirect path from depression and anxiety symptoms at Time 1 to sleep duration at Time 2 through parent and student pressures at Time 2, and also, whether there was a significant indirect path from sleep duration at Time 1 to depression and anxiety symptoms at

Time 2 through parent and student pressures at Time 2. Cross-lagged paths and autoregressive paths for all five study variables were assessed at the two time points.

Chapter 4

4.1 Results

4.1.1 Descriptives

For the PCA analysis, Bartlett's test of sphericity was significant ($\chi 2$ (6) = 2015.34, p < .001) with a Keiser-Meyer-Olkin measure of .533, indicating an adequate sample. The communalities were all above 0.3, further confirming that each item shared some common variance with other items. Given these overall indicators, a PCA was deemed to be suitable. Two components were extracted from the PCA, with "my parents expect too much of me" loading separately from the other three items. For this reason, the "parent pressures" item was kept as a separate mediator in the model, while the "student pressures" measure was formed by a sum score based on the standardization of the other three variables, using SPSS version 28 (127,130).

Sleep duration (in hours) is presented at baseline in Table 1 and Figure 3. Average sleep duration was 7 hours and 54 min (SD=78.94 min) at Time 1 and 7 hours and 28 minutes (SD=79.14 min) at Time 2. Students that reported getting the most sleep were those who self-identified as male, white, and in grade nine (p < .001).

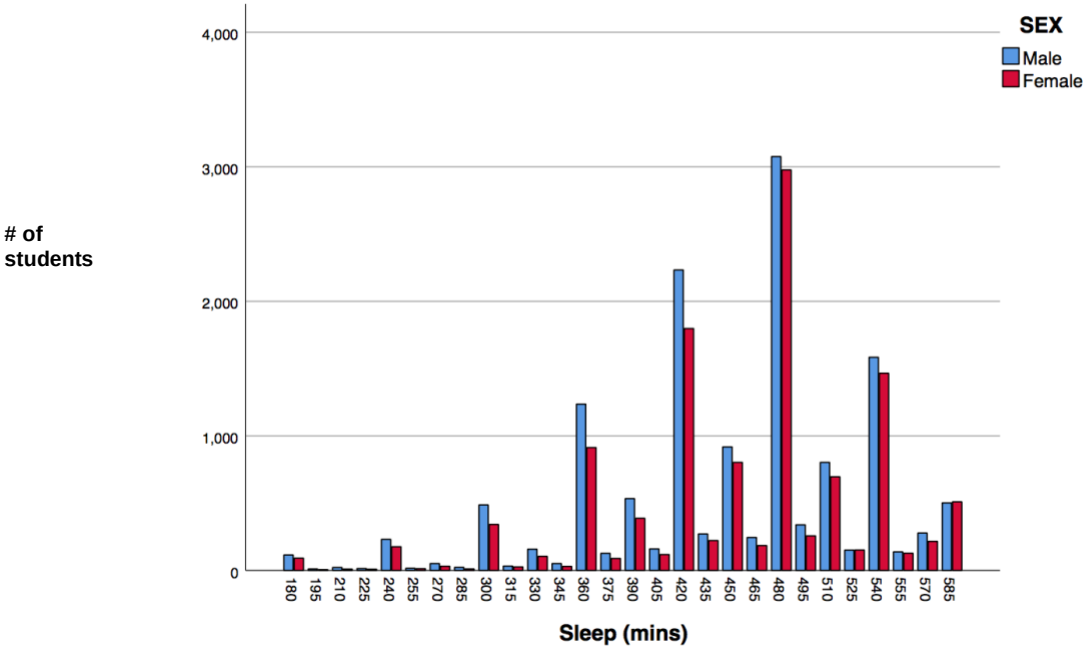
Table 1. Sleep duration (hours) at baseline among youth in Time 1 (2017-2018) of the COMPASS study

		N	M	SD	p-value
Province	British Columbia	3639	7.39	75.27	<.0001
	Alberta	1269	7.31	80.37	
	Ontario	12082	7.25	79.77	
	Quebec	8640	8.05	69.58	
Race/ Ethnicity	White	19838	7.62	77.71	<.0001

	Black	1125	7.26	89.67	
	Asian	3390	7.22	77.18	
	Latin American/ Hispanic	839	7.36	81.62	
	Other	2630	7.38	85.48	
Sex	Male	11818	7.61	77.49	<.0001
	Female	13806	7.49	79.98	
Grade	9	8207	7.63	76.36	<.0001
	10	7900	7.39	76.74	
	11	4738	7.02	76.25	
	12	254	7.04	78.07	
	Other[a]	4457	8.23	70.89	

[a] Secondary I-II in Quebec schools;
M = mean, SD = standard deviation

Figure 3. Sleep duration at baseline (Time 1) by sex



Descriptive statistics for all study variables included in the study for both time points are shown in Table 2.

Table 2. Baseline descriptive statistics for secondary school students linked across Time 1 (2017-2018) and Time 2 (2018-2019) of the COMPASS Study (N= 25,722)

		Time 1		Time 2	
		n	**%**	**n**	**%**
Province	British Columbia	3663	14.2%	3663	14.2%
	Alberta	1272	4.9%	1272	4.9%
	Ontario	12121	47.1%	12121	47.1%
	Quebec	8666	33.7%	8666	33.7%
Sex	Male	13846	54.0%	13823	53.9%
	Female	11818	46.0%	11800	46.1%
Grade	9	8240	32.1%	2014	7.9%
	10	7920	30.9%	8149	31.9%
	11	4757	18.5%	7942	31.0%
	12	255	1.0%	4909	19.2%
	Other[a]	4353	16.9%	2424	9.4%
Race/Ethnicity	White	19895	77.3%	19737	76.7%
	Black	1132	14.4%	1159	4.6%
	Asian	3405	13.2%	3451	13.4%
	Latin American/Hispanic	840	3.3%	878	3.4%
	Other	2639	10.3%	2444	9.5%
Weekly spending money	$0	4680	18.2%	3642	14.2%
	$1 to $10	7430	28.9%	2618	10.2%
	$11 to $40	2834	11.0%	2828	11.0%
	$41 to $100	3535	13.9%	6454	25.1%
	More than $100	3287	12.8%	6210	24.1%
	I do not know	4534	17.6%	3794	14.8%
Smoking	None	2532	9.8%	3916	15.2%
	1 day	522	2.0%	683	2.7%
	2 to 10 days	507	2.0%	640	2.5%
	11 to 29 days	164	0.6%	198	2.8%
	Every day	148	0.6%	213	2.8%
Cannabis use	Never	21077	81.9%	17847	69.4%
	Rare	2537	9.9%	4183	16.3%
	A few times a month	1044	4.1%	1702	6.6%
	A few times a week	643	2.5%	1259	4.9%
	Every day	220	0.9%	478	1.9%
Alcohol use	Never	8048	31.3%	5505	21.4%
	Rare	11305	44.0%	11106	43.2%
	A few times a month	4816	18.7%	6649	25.8%
	A few times a week	1264	4.9%	2133	8.3%
	Every day	58	0.2%	110	0.4%
Parents expect too much	Strongly agree	2292	8.9%	2365	9.2%
	Agree	5229	20.3%	5537	21.5%
	Neither agree nor disagree	9476	36.8%	9416	36.6%
	Disagree	6333	24.6%	6143	23.9%
	Strongly disagree	1907	7.4%	1807	7.0%

Getting good grades is important	Strongly agree	14966	58.2%	13690	53.2%
	Agree	8707	33.9%	9621	37.4%
	Disagree	970	3.8%	1253	4.9%
	Strongly disagree	271	1.1%	389	1.5%
Academic Aspirations	Some high school or less	318	1.2%	273	1.1%
	High School diploma	976	3.8%	896	3.5%
	College/Trade/vocational	4302	16.7%	5001	19.4%
	Univ. Bachelor's degree	4351	16.9%	5568	21.6%
	Master's/PhD/Law/MD	9858	38.3%	9359	36.4%
	I don't know	4975	19.3%	3857	15.0%
		M	**SD**	**M**	**SD**
Time Use (minutes)	Sleep	452.40	78.94	436.80	79.14
	Homework	94.17	73.27	95.12	78.10
	MVPA	107.21	78.51	100.84	76.97
Internalizing symptoms	Depression (CESD-10)	5.90	5.38	6.51	5.57
	Anxiety (GAD-7)	8.13	5.74	9.01	6.0

M = mean, SD = standard deviation, MVPA = moderate to vigorous physical activity. Smoking, cannabis use, and alcohol use defined as use at least once in the last month.
[a] Secondary I-II in Quebec schools.

The majority of the sample identified as white (77.9%), with about half (47.1%) of the students from Ontario. Table 3 shows all descriptive statistics stratified by sex.

Table 3. Descriptive statistics secondary school students linked across Time 1 (2017-2018) and Time 2 (2018-2019) of the COMPASS Study for males (N=11,818) and females (N=13,846).

		Time 1		**Time 2**	
		Males N (%)	**Females N (%)**	**Males N (%)**	**Females N (%)**
Province	British Columbia	1693 (14.3)	1963 (14.2)	1693 (14.3)	1963 (14.2)
	Alberta	602 (5.1)	666 (4.8)	602 (5.1)	666 (4.8)
	Ontario	5715 (48.4)	6370 (46.0)	5715 (48.4)	6370 (46.0)
	Quebec	3808 (32.2)	4847 (35.0)	3808 (32.2)	4847 (35.0)
Grade	9	3817 (32.3)	4406 (31.8)	896 (7.6)	1115 (8.1)
	10	3591 (30.4)	4315 (34.2)	3760 (31.8)	4367 (31.5)
	11	2215 (18.7)	2536 (18.3)	3594 (30.4)	4329 (31.3)
	12	171 (1.4)	84 (0.6)	2331 (19.7)	2568 (18.5)
	Other[a]	1921 (16.2)	2428 (17.5)	1072 (9.1)	1350 (9.8)
Race/ Ethnicity	White	9082 (76.8)	10786 (77.9)	8961 (75.8)	10735 (77.5)
	Black	566 (4.8)	564 (4.1)	614 (5.2)	541 (3.9)
	Asian	1516 (12.8)	1883 (13.6)	1546 (13.1)	1898 (13.7)

	Latin American/Hispanic	372 (3.1)	467 (3.4)	403 (3.4)	473 (3.4)
	Other	1198 (10.1)	1433 (10.3)	1141 (9.7)	1289 (9.3)
Weekly spending money	$0	2409 (20.4)	2260 (16.3)	1878 (15.9)	1752 (12.7)
	$1 to $10	1774 (15.0)	2118 (15.3)	1194 (10.1)	1418 (10.2)
	$11 to $40	1586 (13.4)	1940 (14.0)	1297 (11.0)	1527 (11.0)
	$41 to $100	2457 (20.8)	3115 (22.5)	2715 (23.0)	3727 (26.9)
	More than $100	1615 (13.7)	1666 (12.0)	3026 (25.6)	3173 (22.9)
	I do not know	1890 (16.0)	2641 (19.1)	1619 (13.7)	263 (13.6)
Smoking	None	1188 (10.1)	1339 (9.7)	1833 (15.5)	2070 (15.0)
	1 day	229 (1.9)	291 (2.1)	339 (2.9)	341 (2.5)
	2 to 10 days	252 (1.3)	253 (1.8)	332 (2.7)	308 (2.2)
	11 to 29 days	80 (0.7)	84 (0.6)	102 (0.9)	96 (0.7)
	Every day	87 (0.7)	61 (0.4)	119 (1.0)	94 (0.7)
Cannabis use	Never	9612 (84.3)	11418 (82.5)	8042 (68.0)	9763 (70.5)
	Rare	1116 (9.4)	1415 (10.2)	1793 (15.2)	2382 (17.2)
	A few times a month	496 (4.2)	547 (4.0)	801 (6.8)	898 (6.5)
	A few times a week	348 (2.9)	294 (2.1)	713 (601)	542 (3.9)
	Every day	134 (1.1)	85 (0.6)	306 (2.6)	171 (1.2)
Alcohol use	Never	3849 (32.6)	4180 (30.2)	2752 (23.3)	2737 (19.8)
	Rare	4977 (42.1)	6303 (45.5)	4787 (40.5)	6291 (45.4)
	A few times a month	2169 (18.4)	2638 (19.1)	2838 (24.0)	3800 (27.4)
	A few times a week	661 (5.6)	600 (4.3)	1214 (10.3)	916 (6.6)
	Every day	41 (0.3)	17 (0.1)	88 (0.7)	21 (0.2)
Parents expect too much	Strongly agree	1032 (8.7)	1255 (9.1)	1048 (8.9)	1313 (9.5)
	Agree	2428 (20.5)	2787 (20.1)	2530 (21.4)	2987 (21.6)
	Neither agree nor disagree	4608 (39.0)	4847 (35.0)	4686 (39.7)	4714 (34.0)
	Disagree	2752 (23.3)	3567 (25.8)	2585 (21.9)	35.45 (25.6)
	Strongly disagree	715 (6.1)	1190 (8.6)	693 (5.9)	1109 (8.0)
Getting good grades is important	Strongly agree	6094 (51.6)	8843 (63.9)	5344 (45.2)	8312 (60.0)
	Agree	4501 (38.1)	4187 (30.2)	4989 (42.2)	4622 (33.4)
	Disagree	601 (5.1)	365 (2.6)	769 (6.5)	476 (3.0)
	Strongly disagree	178 (1.5)	91 (0.7)	249 (2.1)	136 (1.0)
Academic Aspirations	Some high school or less	187 (1.6)	130 (0.9)	168 (1.4)	105 (0.8)
	High School diploma	622 (5.3)	351 (2.5)	579 (6.1)	313 (2.3)
	College/Trade/vocational	2481 (21.0)	1819 (13.1)	2937 (24.9)	2055 (14.8)
	Univ. Bachelor's degree	2099 (17.8)	2246 (16.2)	2547 (21.6)	3008 (21.7)
	Master's/PhD/Law/MD	3487 (29.5)	6347 (45.8)	3185 (27.0)	6155 (44.5)
	I don't know	2459 (20.8)	2498 (18.0)	1895 (16.5)	1894 (13.7)

Note. [a] Secondary I-II in Quebec schools.

On average, males had longer sleep durations than females, and this finding was consistent throughout all grades. Females on average had higher depression and anxiety symptoms (Figures 3 and 4, respectively) than males.

Figure 4. Anxiety (GAD-7) Scores at baseline (Time 1) by sex

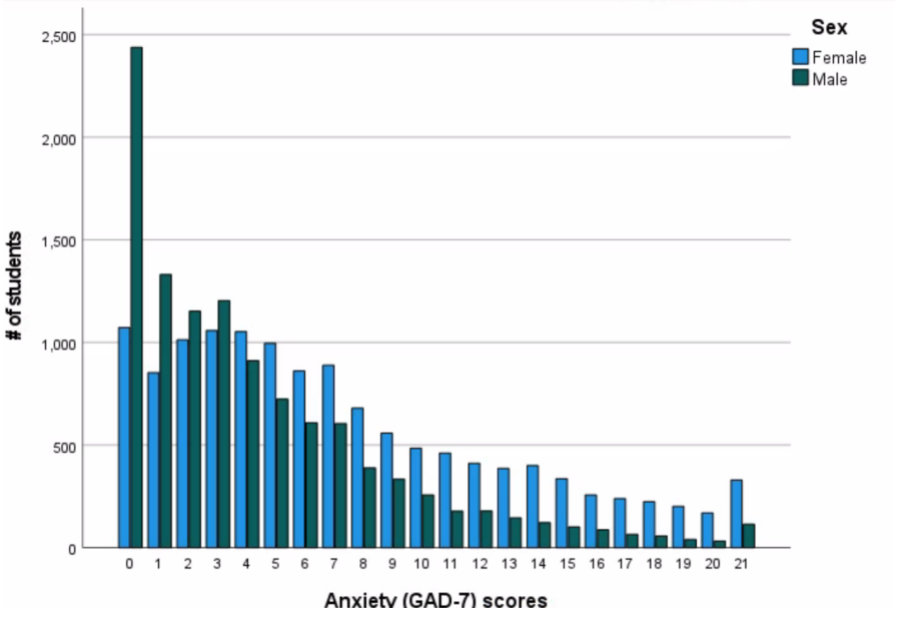
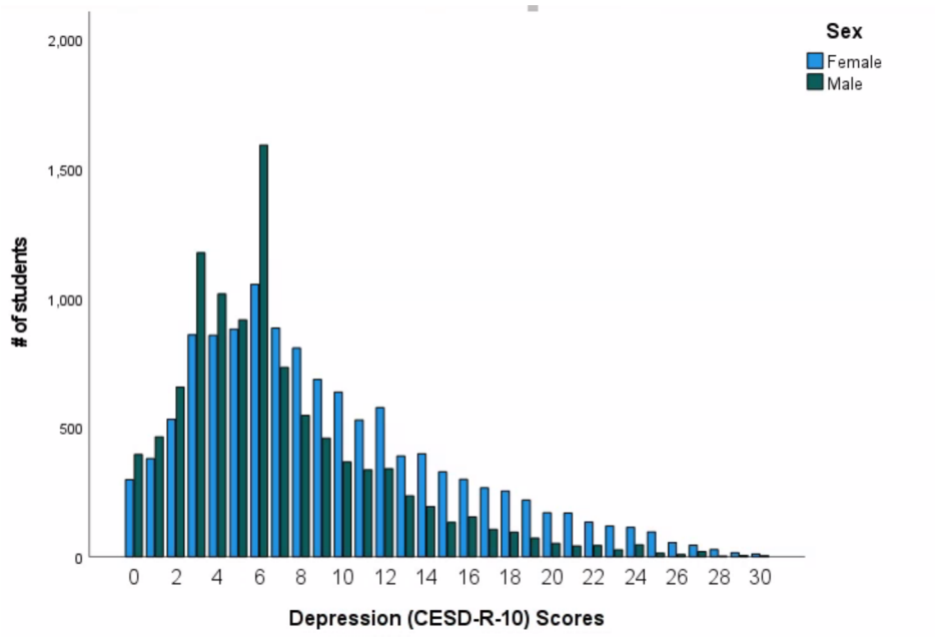


Figure 5. Depression (CESD-R-10) Scores at baseline (Time 1) by sex



In both waves, females scored higher on the perceived parent pressures item and on all of the student pressure measures (i.e., higher homework times, academic aspirations, and perceived importance of good grades) than males. Table 4 presents the PCA for the "student pressures" variable, and Table 5 shows the paired samples t-tests to determine if study variables significantly differed across waves.

Table 4. Principal Components Analysis for the "Student Pressures" and "Parent Pressures" Variables

Variable	1 Student Pressures	2 Parent Pressures
Parent Expectations	-.01	.32
Good Grades	.59	-.12
Academic Aspirations	.53	-.03
Homework Time	.43	.23

Table 5. Paired samples t-tests of study variables across waves among secondary students linked from Time 1 (2017-2018) and Time 2 (2018-2019) of the COMPASS Study.

		Time 1		Time 2		*t-value*		*df*		*Cohen's d*	
Variable		Females	Males	Females	Males	Females	Males	Females	Males	Females	Males
Sleep (min)	**M**	449.22	456.37	433.88	441.19	23.17*	20.93*	11704	13770	0.24	0.20
	SD	(79.95)	(77.41)	(80.03)	(77.78)						
Homework Time (min)	**M**	109.77	75.91	113.15	73.83	-5.70*	3.51*	11704	13770	0.03	0.05
	SD	(76.43)	64.81)	(81.44)	(67.94)						
MVPA (min)	**M**	97.71	118.44	90.57	113.04	11.92*	7.12*	11463	13463	0.06	0.10
	SD	(97.71)	(84.32)	69.97)	(82.39)						
Anxiety (GAD-7)	**M**	7.26	4.26	8.00	4.71	-16.51*	-10.19*	10439	12306	0.10	0.15
	SD	(5.66)	(4.53)	(5.70)	(4.88)						
Depression (CESD-10)	**M**	9.27	6.80	10.26	7.51	-18.85*	-14.05*	9175	10972	0.15	0.18
	SD	(6.15)	(4.89)	(6.26)	(5.34)						

*Significant at the p<0.0001 level (2-tailed).
M = mean, SD = standard deviation, MVPA = moderate to vigorous physical activity.

Correlations for all study variables are presented in Table 6 (Time 1 and 2).

Table 6. Pearson Table Correlations for Study Variables for Time 1 (2017-2018) and Time 2 (2018-2019) of the COMPASS Study.

Variable	1	**2**	**3**	**4**	**5**
1.Sleep	-				
2.Student Pressures	(T1) -0.15* (T2) -0.14*	-			
3.Parent Pressures	(T1) 0.12* (T2) -0.13*	(T1) -0.05* (T2) -0.06*	-		
4.Anxiety (GAD-7)	(T1) -0.24* (T2) -0.24*	(T1) 0.13* (T2) -0.14*	(T1) -0.22* (T2) -0.21*	-	
5.Depression (CESD-10)	(T1) -0.28* (T2) -0.29*	(T1) 0.18* (T2) -0.15*	(T1) -0.27* (T2) -0.26*	(T1) 0.75* (T2) 0.77*	-

Note: n's ranged from 22362-25630.
*****Significant at the p<0.0001 level

4.1.2 Cross-Lagged Models

Fit statistics for autoregressive and cross-lagged models of sleep duration are shown in Table 7.

Table 7. Fit statistics for autoregressive and cross-lagged models of sleep duration, student and parent pressures, and anxiety and depression symptoms among adolescents that participated in Years 6 and 7 of the COMPASS Study.

Student and parent pressures, and anxiety and depression symptoms demonstrated acceptable model fit (χ 2(111) = 131.56, p = 0.001; CFI = 0.99; RMSEA = 0.05; 95% CI [0.03, 0.07]; SRMR = 0.03). Table 8 presents standardized parameter estimates in the full sample.

Index[1]	Full sample
CFI	1.000
TLI	1.000
RMSEA	0.000 (0.00, 0.00)

[1]For the CFI and TLI, values closer to 1 indicate better fit, with values >0.95 indicating good fit. For the RMSEA, values closer to 0 indicate better fit, with values of <0.06 indicating good fit.

Table 8. Standardized parameter estimates of autoregressive and cross-lagged associations between sleep duration, student and parent pressures, and anxiety and depression symptoms among adolescents that participated in Time 1 and Time 2 of the COMPASS Study.

	Parameter Estimate	β	95% CL	*p*
Autoregressive	SLEEP1 → SLEEP2	0.44	0.42, 0.45	**<0.0001**
	SPRES1→SPRES2	0.64	0.62, 0.65	**<0.0001**
	FAM1→FAM2	0.46	0.45, 0.47	**<0.0001**
	ANX1 → ANX2	0.48	0.46, 0.49	**<0.0001**
	DEP1 → DEP2	0.44	0.43, 0.45	**<0.0001**
Cross-lagged	SLEEP1 → ANX2	-0.03	-0.04, -0.02	**<0.0001**
	SLEEP1 → DEP2	-0.05	-0.06, -0.04	**<0.0001**
	SLEEP1→ SPRES2	0.01	0.01, 0.03	**0.040**
	SLEEP1→ FAM2	-0.02	-0.03, -0.01	**0.001**
	FAM1→SLEEP2	-0.03	-0.04, -0.02	**<0.0001**
	FAM1→SPRES2	-0.00	-0.01, 0.01	0.901

	FAM1→ANX2	-0.00	-0.01, 0.01	0.842
	FAM1→DEP2	0.04	0.03, 0.05	<**0.0001**
	SPRES1→SLEEP2	0.00	-1.05, 1.29	0.865
	SPRES1→FAM2	0.01	-0.01, 0.01	0.060
	SPRES1→ANX2	0.04	0.03, 0.06	<**0.0001**
	SPRES1→DEP2	-0.01	-0.02, -0.00	0.051
	ANX1 → SLEEP2	-0.03	-0.04, -0.01	**0.002**
	ANX1 → DEP2	0.18	0.16, 0.19	<**0.0001**
	ANX1→SPRES2	0.06	0.04, 0.07	<**0.0001**
	ANX1→FAM2	0.01	-0.01, 0.02	0.507
	DEP1 → SLEEP2	-0.07	-0.09, -0.06	<**0.0001**
	DEP1→ SPRES2	-0.04	-0.05, -0.02	<**0.0001**
	DEP1→FAM2	0.07	0.05, 0.08	<**0.0001**
	DEP1 → ANX2	0.17	0.15, 0.18	<**0.0001**
Indirect Effects	SLEEP→ FAM→DEP	-0.03	-0.04, -0.01	**0.002**
	SLEEP→FAM→ANX	-0.02	-003, -0.01	**0.002**
	SLEEP→SPRES→DEP	-0.01	-0.01, 0.00	0.055
	SLEEP→SPRES→ANX	0.00	0.00, 0.01	0.119
	DEP→ FAM→SLEEP	-0.02	-0.04, -0.03	**0.004**
	DEP→SPRES→SLEEP	-0.01	-0.02, 0.03	0.363
	ANX→FAM→SLEEP	-0.01	-0.06, 0.05	0.817
	ANX→SPRES→SLEEP	0.01	-0.05, 0.02	0.334

SPRES = student pressures; FAM = parental pressures (family expects too much); DEP = depressive symptoms; ANX = anxiety symptoms; SLEEP = sleep duration. Models control for grade, weekly-spending money, physical activity, substance use, and ethnicity, and adjusted for school-level clustering.

Since different variables are often measured in different units in behavioral research, comparing their standardized effects will lead to a more meaningful conclusion, because they are affected less by the units of measurement (131). Autoregressive associations show that Time 1 was predictive of Time 2 in measures of sleep, student pressures, parent pressures, depressive symptoms, and anxiety symptoms in the full sample and in both females and males. A positive association was identified between mean anxiety scores at Time 1 and mean depression scores at Time 2 ($\beta = 0.18$, 95% CL [0.16, 0.19]). This association was reciprocal, whereby mean depression score in Time 1 also predicted mean anxiety scores in Time 2 ($\beta = 0.17$, 95% CL [0.15, 0.18]). Both anxiety and depression scores at Time 1 were predictive of sleep duration at

Time 2 and vice-versa. Longer sleep duration in Time 1 was associated with lower anxiety symptoms in Time 2 (β = -0.03, 95% CI [-0.04, -0.02]). In the opposite direction, anxiety symptoms at Time 1 were associated with shorter sleep duration at Time 2 (β = -0.03, 95% CL [-0.04, -0.01]). Longer sleep in Time 1 was also associated with lower depression scores in Time 2 (β = -0.05, 95% CL [-0.06, -0.04]) and lower depression scores in Time 1 predicted longer sleep duration in Time 2 (β = -0.07, 95% CL [-0.09, -0.06]). Student pressures in Time 1 was not predictive of parent pressures in Time 2, and the same can be said about the reverse direction.

Table 9 presents standardized parameter estimates for the stratified model in females and males.

Table 10. Standardized parameter estimates, stratified by sex, of the autoregressive and cross-lagged associations between sleep duration, student and parent pressures, and anxiety and depression symptoms, among adolescents that participated in Time 1 and Time 2 of the COMPASS Study.

	Females			**Males**		
Parameter Estimate	**β**	**95% CL**	***p***	**β**	**95% CL**	***p***
Autoregressive						
SLEEP1 →SLEEP2	0.44	0.43, 0.46	**<0.001**	0.43	0.41, 0.44	**<0.001**
SPRES1→SPRES2	0.61	0.59, 0.62	**<0.001**	0.60	0.59, 0.62	**<0.001**
FAM1→ FAM2	0.48	0.46, 0.49	**<0.001**	0.43	0.41, 0.45	**<0.001**
GAD1 → GAD2	0.46	0.44, 0.48	**<0.001**	0.42	0.40, 0.45	**<0.001**
CESD1 → CESD2	0.46	0.43, 0.48	**<0.001**	0.39	0.37, 0.42	**<0.001**
Cross-lagged						
SLEEP1 → ANX2	-0.02	-0.04, -0.01	**0.016**	-0.04	-0.05, -0.03	**<0.001**
SLEEP1 → DEP2	-0.06	-0.07, -0.04	**<0.001**	- 0.05	-0.06, -0.04	**<0.001**
SLEEP1 → SPRES2	-0.01	-0.02, 0.01	0.486	0.04	0.02, 0.05	**<0.001**
SLEEP1 → FAM2	-0.02	-0.04, -0.01	**0.006**	-0.01	-0.03, 0.00	0.206
FAM1 → SLEEP2	-0.03	-0.05, -0.02	**<0.001**	-0.01	-0.03, 0.00	0.135
FAM1 → SPRES2	0.02	0.01, 0.03	**0.014**	0.00	-0.01, 0.01	0.979
FAM1 → ANX2	0.02	0.01, 0.03	**0.023**	0.00	-0.01, 0.02	0.801
FAM1 → DEP2	0.06	0.05, 0.07	**<0.001**	0.04	0.02, 0.05	**<0.001**
SPRES1 →SLEEP2	-0.03	-0.04, -0.01	**<0.001**	0.04	0.02, 0.05	**<0.001**
SPRES1 → FAM2	0.03	0.014, 0.04	**0.002**	0.01	-0.00, 0.03	0.219

SPRES1 → ANX2	0.01	-0.04, 0.03	0.279	0.01	-0.01, 0.03	0.329
SPRES1 → DEP2	-0.04	-0.06, -0.03	**<0.001**	-0.03	-0.04, -0.01	**0.002**
ANX1 → SLEEP2	-0.02	-0.04, -0.00	0.055	-0.03	-0.05, 0.00	0.055
ANX 1 → DEP2	0.13	0.11, 0.15	**<0.001**	0.19	0.17, 0.21	**<0.001**
ANX1 → SPRES2	0.03	0.01, 0.04	**0.013**	0.03	0.01, 0.05	**0.003**
ANX1 → FAM2	0.01	-0.02, 0.03	0.541	0.02	-0.00, 0.04	0.146
DEP1 → SLEEP2	-0.08	-0.10, -0.06	**<0.001**	-0.06	-0.09, -0.04	**<0.001**
DEP1 → SPRES2	-0.05	-0.07, -0.03	**<0.001**	-0.04	-0.06, -0.02	**0.001**
DEP1 → FAM2	0.07	0.05, 0.10	**<0.001**	0.06	0.04, 0.08	**<0.001**
DEP1 → ANX2	0.16	0.14, 0.18	**<0.001**	0.16	0.13, 0.18	**<0.001**
Indirect Effects						
SLEEP→ FAM→DEP	-0.04	-0.06, -0.02	**<0.001**	-0.01	-0.02, 0.03	0.204
SLEEP→FAM→ANX	-0.03	-0.09, -0.04	**<0.001**	-0.00	-0.01, 0.02	0.208
SLEEP→SPRES→DEP	-0.01	-0.02, -0.01	**<0.001**	-0.02	-0.02, -0.01	**0.002**
SLEEP→SPRES→ANX	-0.03	-0.10, -0.09	**<0.001**	0.00	-0.01, 0.04	0.625
DEP→FAM→SLEEP	-0.04	-0.06, -0.02	**0.007**	-0.03	-0.02, 0.01	0.774
DEP→SPRES→SLEEP	0.01	-0.01, 0.2	0.782	-0.02	-0.04, 0.02	0.128
ANX→FAM→SLEEP	-0.00	-0.01, 0.01	0.940	-0.00	-0.01, 0.04	0.116
ANX→SPRES→SLEEP	-0.00	-0.01, 0.02	0.779	0.03	0.00, 0.03	0.822

SPRES = student pressures; FAM = parental pressures (family expects too much); CESD = depressive symptoms; GAD7 = anxiety symptoms; SLEEP = sleep duration. Models control for grade, weekly-spending money, physical activity, substance use, and ethnicity, and adjusted for school-level clustering.

Similar to the full sample, shorter sleep duration among females in Time 1 was associated with higher anxiety symptoms (β = -0.02, 95% CL [-0.04, -0.01]), but there was no association for the reverse direction. For depression symptoms, there were bi-directional associations, with shorter sleep durations at Time 1 predicting higher depression symptom scores at Time 2 (β = -0.06, 95% CL [-0.07, -0.04]) and vice versa (β = -0.08, 95% CL [-0.10, -0.06]). Though sleep did not predict student pressure scores one year later, the reverse relationship was significant; that is, higher student pressure scores at Time 1 were predictive of a shorter sleep duration at Time 2 (β = -0.03, 95% CL [-0.04, -0.01]). Sleep and parent pressures were found to have a significant bi-directional association; whereby shorter sleep duration at Time 1 predicted higher self-reported parent pressures at Time 2 (β = -0.06, 95% CL [-0.04, -0.01]) and higher parent pressures

predicted shorter sleep duration in Time 2 (β = -0.03, 95% CL [-0.05, -0.02]). In the full sample, higher anxiety in Time 1 was associated with higher student pressures in Time 2 (β = 0.06, 95% CL [0.04, 0.07]). However, higher depression in Time 1 was associated with lower student pressures in Time 2 (β = -0.04, 95% CL [-0.05, -0.02]).

In females only, student pressure scores at Time 1 did not predict anxiety scores in Time 2, but higher Time 1 anxiety scores predicted higher Time 2 student pressure scores (β = 0.03, 95% CL [0.01, 0.04]). As well, parent pressure scores at Time 1 were predictive of anxiety scores at Time 2 (β = 0.02, 95% CL [0.01, 0.03]), but the reverse relationship was not significant.

In males, there were also significant cross-lagged associations between sleep at Time 1 and depression scores in Time 2 (β = -0.05, 95% CL [0-0.06, -0.04]) and vice-versa (β = -0.06, 95% CL [-0.09, -0.04]). Sleep in Time 1 predicted anxiety scores in Time 2 (β = -0.04, 95% CL [-0.05, -0.03]), but the reverse association was not significant. Whereas parent pressures and sleep duration were found to be negatively associated in both directions in females, this relationship was not seen in either direction in males. However, sleep at Time 1 was positively predictive of self-reported student pressures at Time 2 (β = 0.04, 95% CL [0.02, 0.05]), in which more sleep predicted greater student pressures. Perceived parent pressures was not predictive of anxiety scores, but anxiety scores at Time 1 were predictive of student pressure scores at Time 2 (β = 0.03, 95% CL [0.01, 0.05]), with higher anxiety associated with higher student pressure scores.

4.1.3 Bi-Directional Mediation Model

To assess the potential mediating roles of both parent and student pressures between sleep and internalizing symptoms, we tested two separate mediation models (based on a test of

indirect effects). Specifically, we assessed whether: (1) sleep duration in high school students at Time 1 would predict internalizing symptoms through student pressures at Time 2, and (2) sleep duration at Time 1 would predict internalizing symptoms through parent pressures at Time 2.

Bootstrap method analyses for indirect effects indicated a significant indirect path from Time 1 sleep duration to Time 2 depression symptoms through Time 2 parent pressures (β = -0.03, 95% CL [-0.04, -0.01]). That is, longer sleep duration was associated with lower perceived-parent pressures, which in turn, was related to lower depressive symptoms. There was a similar story with Time 2 anxiety symptoms to Time 2 sleep duration through Time 1 parent pressures (β = -0.02, 95% CL [-0.03, -0.01]). Student pressures did not play a mediating role in the relationship between sleep at Time 1 and either anxiety or depressive symptoms at Time 2. However, when looking at the reverse direction, there was a significant pathway between depression scores at Time 1 and sleep duration at Time 2 through family pressures (β = -0.02, 95% CL [-0.04, -0.03]). No other pathways when looking at Time 2 anxiety or depression symptoms appeared to be significant.

When looking at these relationships in females only, there were significant indirect paths between sleep at Time 1 to depression symptoms at Time 2 through both student pressures (β = -0.01, 95% CL [-0.02, -0.01]) and parent pressures (β = -0.04, 95% CL [-0.06, -0.02]) at Time 2. Shorter sleep duration was associated with higher student and parent pressures, which in turn was related to higher depressive symptoms. When looking at the reverse association, there was a significant pathway between depression scores at Time 1 to sleep through Time 2 family pressures β = -0.04, 95% CL [-0.06, -0.02]). Additionally, there were significant indirect pathways from sleep at Time 1 to anxiety symptoms at Time 2 through both student pressures (β

= -0.03, 95% CL [-0.10, -0.09]) and parent pressures (β = -0.03, 95% CL [-0.09, -0.04]), but the reverse direction was not found to be significant.

In males, these relationships did not uphold. There was a significant indirect pathway from Time 1 sleep duration to Time 2 depression symptoms through Time 2 student pressures (β = -0.02, 95% CL [-0.02, -0.01]). However, when tested with parent pressures, this indirect path was not significant. There were no significant indirect pathways when looking at the relationships between sleep and anxiety symptoms through either student or parent pressures at Time 2. Lastly, there was no significant pathway when looking at Time 1 depression/anxiety symptoms to Time 2 sleep through student or parent pressures.

Chapter 5

5.1 Discussion

To our knowledge, this study is the first to examine parent and student pressures as mediators in the association between sleep and internalizing symptoms. In a large sample of Canadian adolescents, results supported the hypothesized bi-directional relationships between sleep duration and depression and anxiety symptoms across one year, while controlling for relevant covariates. Shorter sleep duration predicted greater depression and anxiety symptoms and vice versa. Mediation results varied by sex and direction of effects. In females, both parent and student pressures mediated the association between baseline sleep duration and later depression and anxiety symptoms, and in the reverse direction, family, but not student pressures, mediated the association between depression and sleep duration. In contrast, the only indirect effect that resulted in males was for student pressures in the association between sleep and depression symptoms. Results align with previous cross-sectional and longitudinal evidence

indicating that adolescents with shorter sleep durations generally show more depressed and anxious tendencies (40,88,89,94). The current study adds to these findings and provides a more complete picture of how short sleep may affect the mental health of high school students. Results further strengthen calls that short sleep should be taken seriously given the potential increased risk of internalizing symptoms and difficulties managing relevant stressors during adolescence.

5.1.1. Sleep and Internalizing Symptoms

In both males and females, shorter sleep duration at baseline predicted higher depression and anxiety symptoms one-year later. In the reverse direction, higher depression symptoms predicted shorter sleep duration at follow up in all models; however, while anxiety symptoms predicted shorter sleep in the full sample, results were not statistically significant in the stratified models for either sex. Sleep disorders have been established as precursors in the development of depression (45); the current study suggests that shorter sleep duration (i.e., below the recommended guidelines) may also predict greater depression and anxiety symptoms in adolescents. Over time, depression symptoms may in turn lead to shorter sleep duration, which could potentially contribute to an adverse cyclic relationship of deteriorating mental health and sleep. Previous studies have found that both sleep disorders and depression are linked to dysfunction of the cholinergic neurotransmitter system and prefrontal cortex as well as increased limbic system activity, highlighting a mechanism linking sleep disorders and depressive problems (65,132).

Previous research has generally assessed prospective associations between anxiety and sleep problems, rather than sleep duration. Similar to the current findings, a recent Dutch prospective cohort study found poor sleep to precede high anxiety in early and mid-adolescence, but no association was found in the reverse direction across one year (133). Previous longitudinal studies have also provided evidence that sleep problems predict anxiety symptoms across

childhood, adolescence, and young adulthood (46,134). In the Adolescent Brain Cognitive Development (ABCD) study, shorter total sleep time and greater sleep disturbance at baseline were associated with greater internalizing, externalizing, and depression scores at one-year follow up, but when controlling for baseline mental health, only sleep disturbance remained associated with symptoms, particularly depression (135). In terms of the reverse direction, some previous studies have found a link between anxiety symptoms and subsequent sleep problems (86,135), while other research either did not find an association (85,136) or only indicated weak relationships (88). Further research is needed to confirm our bi-directional and sex-stratified results examining anxiety and sleep in a nonclinical sample of adolescents.

These differences in results for anxiety and depression when examined separately in males and females are not what we hypothesized given the high comorbidity (52,54). That said, the high comorbidity may contribute to null findings for anxiety given that anxiety models controlled for depression symptoms and vice versa. It is also plausible that the null results for baseline anxiety symptoms predicting shorter sleep reflect the one-year period between measures. The anxiety and depression scales assess symptoms within the last two weeks and one week, respectively, while the sleep measure refers time “usually” spent sleeping. Moreover, results were generally consistent across sex and marginal in effect size, which may explain the statistical significance of the pathway from anxiety to sleep in full sample, but not in the sex stratified model. Previous research has pointed to evidence that short sleep and depression symptoms are highly correlated among females, and that because of this, females tend to be more likely than males to develop depression through their adolescent and adult life (137,138). Overall, while our results suggest that short sleep duration may contribute to the emergence of

internalizing symptoms in adolescents, further research is needed to examine bi-directional associations with anxiety (139).

5.1.2. Student and Parental Pressures and Internalizing Symptoms

In the full sample, greater student pressures predicted lower depression symptoms, and greater depression symptoms predicted lower student pressures one year later. Conversely, student pressures were not associated with anxiety symptoms one year later in either sex, but greater anxiety symptoms predicted greater student pressures. While contrary to our hypotheses, the negative bi-directional relationship between depression symptoms and student pressures, and null finding for student pressures and later anxiety symptoms, were not entirely unexpected given the measures used. The items comprising student stressors in the current study did not explicitly assess perceptions of stress or distress regarding school and may be more indicative of concepts such as academic engagement, perseverance, dedication, or motivation. The depression results are consistent with research that has found a negative relationship between negative affect in adolescents and academic performance (12). Similar to the current study, in previous research using COMPASS cross-sectional data, lower depression symptoms were associated with better grade levels, and anxiety symptoms were positively associated with days missed due to health, classes skipped, and frequently leaving homework incomplete (140). Relationships between student pressures and anxiety may vary by individual characteristics. For instance, students with perfectionistic attributes may be prone to experiencing higher anxiety symptoms, and in turn, place more pressure on school performance (141). In de Anda et al.'s (2000) investigation of stressors most frequently encountered by high school students, most adolescents reported often experiencing stress related to studying for tests, getting good grades, completing homework, and managing time (22). In a qualitative study of students attending a high-achieving school, their

own high standards for school performance and aspirations were discussed as part of their identity and sources of stress (142).

We also found that higher family pressures predicted higher anxiety and depression symptoms in females, and higher depression, but not anxiety symptoms, in males. These results partially support what we hypothesized. Sex differences align with previous research, with females reporting higher internalizing symptoms and perceptions of student and parental pressures than males (133,134). Parents' aspirations and expectations play a critical role in shaping adolescents' goals and dispositions. Results of this study add to existing findings that male and female adolescents appear to react differently to home influences (143). Our findings may reflect sociocultural gender differences, in which girls have been said to encounter socially shaped contradicting expectations and rapidly expanding roles that may be stressful and difficult to manage, particularly if parent support is inadequate (25). Positive communication and involving parents in the education of students may increase the overall well-being of students (144). Previous literature suggests that supportive communication can improve immediate outcomes for already stressed individuals, and may deter depression and anxiety symptoms by encouraging functioning coping behaviour in the academic context (84). Adolescents may benefit by having parents be emotionally available during highly stressful times.

5.1.3. Student and Parental Pressures and Sleep Duration

Overall, results supported links between academic stress experienced by students and sleep duration (37,38). However, males and females appeared to differ in their experiences of school and parental pressures, contributing to contrasting associations with sleep duration. Higher parental expectations and sleep duration were found to be negatively associated in both directions in females, but this relationship was not seen in either direction in males. Student

pressures were negatively associated with sleep duration one year later in females, and positively associated with sleep in males. There results do not coincide with previous studies that have found no gender differences in the association between sleep and student-related stress . As discussed above, the positive association found in males may reflect the items used to assess student pressures, which do not assess distress regarding school, and rather may reflect motivation, engagement, and performance. Females are more likely to have higher grades and display greater diligence in school (148), but also experience more exhaustion and perceived inadequacy than males (22). Thus, females tend to sleep less than their male counterparts (148). Female adolescents can be more prone to ruminate than males, thus negatively affecting females' sleep (149). Sociocultural gender norms may contribute, with girls expected to be more emotionally sensitive and expressive, and to experience more school performance pressure (25). Results are in line with previous research indicating female students were more likely to report poor sleep, a higher subjective stress level, and an increased level of social support as a coping strategy (69). This study is consistent with the broader literature that adolescents do not sleep enough in general due to academic stress (12), and adds important evidence on the bidirectional associations and sex differences.

5.1.4. Student and Parental Pressures as Mediators in the Association between Sleep and Internalizing Symptoms

Lastly, we tested bi-directional indirect effects of both student and parent-related stressors in the association between sleep duration and depression and anxiety symptoms. In the full sample, significant bi-directional indirect effects were found for family pressures as a mediator in the association between sleep and depression symptoms; whereas student pressures did not mediate the association between sleep and depression and anxiety symptoms in either

direction. However, when results were stratified by sex, in females, significant indirect effects were found for both parental and student pressures in the association between sleep at baseline and later depression and anxiety symptoms. In males, perceived student pressures mediated the association between sleep and depressive symptoms only, but not anxiety, and no mediation effect was found for parental pressures. The results suggest that both student and parental pressures appear more important to those associations between sleep and internalizing symptoms in females than males. That is, perceived high parent expectations and student pressure at least partially account for the relationship between sleep duration and mental ill-health in females. It is highly possible that short sleep will intensify individual's sensitivity to stressors, and in turn, their negative emotions (150). Broadly, findings from this study highlight the importance of adopting healthy sleep schedules (21). Future research needs to investigate the role of other factors that could contribute to trends in the relationship between sleep and adolescent mental well-being, such as changes in the quality of family relationships, as well as the role of peer relationships, and how these differ by sex and gender.

Results align with previous research indicating perceived high demands in school and high responsibility-taking are contributors to mental strain in adolescent girls (25). There is also some evidence to suggest that girls respond more negatively to competitive learning conditions, are more likely to be exposed to stressful events, and, as a result, more vulnerable to negative affect (151). At the same time, both sleep quantity and quality are impaired, as a consequence of a dramatic delay of sleep timing induced by increasing psychosocial and environmental demands on school-aged youth (151). Taken together, mental ill-health is a multidimensional construct that can show different trajectories and may have differential susceptibilities by sex and gender. School-based interventions may be beneficial to enhance coping skills and stress reduction

strategies, particularly among females. Students should be supported in developing the intrapersonal and interpersonal skills needed to navigate the stressors related school, as well as in their familial environments. Parents, public health, and schools are encouraged to promote a healthy study-sleep schedule among adolescents. Previous research found shifting as little as 10 minutes of homework time to sleep was beneficial for adolescent mental health.(113)

5.2. Implications and Future Research

This research provides new insights into the nature and directionality of associations between student-related stressors, sleep, and internalizing symptoms over time, and suggests that interventions promoting regular sleep schedules in adolescence may help mitigate risk for stress-related psychopathology. The current study supports previous literature indicating the importance of maintaining adequate sleep in adolescence for reducing the risk of developing internalizing symptoms. Sleep might be particularly important during periods of greater plasticity in development (15). Future studies spanning longer time frames are needed to determine the strength of relationships between sleep and adjustment during various developmental periods

Clinicians, educators, parents and policy makers should acknowledge that the pervasive effects of chronic sleep debt in adolescents have become a serious public health issue. For instance, while it may be administratively convenient to begin high school classes early, the results of the current study support research suggesting that later school start-times would be more appropriate for adolescents attending high school (152). Intervention studies with long-term follow up should examine whether sleep-related interventions for inadequate sleep may protect adolescents from negative psychological outcomes.

5.3 Strengths and Limitations

This study has several strengths, including a large sample size, the use of valid and reliable measures of depression and anxiety, and two waves of data, allowing bi-directional and mediational relationships to be tested. Existing research has highlighted the importance of sleep in clinical populations, in terms of the management of mental illness symptoms, and the impact of mental illness on sleep, but more research needed at the population level in nonclinical samples. Another important strength was the use of the cross-lagged panel models, which makes use of longitudinal data to infer underlying processes of reciprocal causality among a set of constructs, works well with larger sample sizes, and can examine directionality between variables (118). An additional advantage of this study was the inclusion of both student and parent related stressors as potential mediators, as these have been previously shown to affect both sleep duration and internalizing symptoms. At the high school level, future research should examine other common stressors, such as social stressors (i.e., social acceptance and friendship quality), longitudinally and by gender.

Another strength of the current study is the use of passive consent protocols, which improve response rates and the generalizability (153,154). No student names are used to help preserve perceptions of confidentiality and anonymity and promote honest reporting. This is particularly important when asking students about their self-reported behaviours that may be linked with symptoms of depression and/or anxiety.

However, this study is not without limitations. First, 19.3% of the sample (4,975 of students in Time 1) and 15% (3,857 students in Time 2) answered “I don’t know” on the academic aspirations component of student pressures. This response option was not included in the factor analysis as this could be deemed as a non-response to the question. We also removed

students who reported less than three hours of sleep, consistent with previous studies (28,155). At baseline, 5.7% and 3.2% of the sample answered that they had less than three hours or zero hours of sleep, respectively. This is a limitation to the study because removing these students may have led to an overestimation of average sleep durations. However, there are a number of reasons why students might have responded this way. For instance, the COMPASS survey asks students how much time spent "per day" they usually spend sleeping, so it is possible that students did not understand the question (e.g., reporting nap-time sleep, careless responding, etc.). Though this is a limitation, all potential explanations indicate these responses should be excluded from the analysis (86,113). Additionally, the COMPASS survey restricts any reports greater than 9 hours and 45 minutes, which may also limit the interpretations that can be made for those getting additional sleep.

Sleep duration is a necessary resource for psychosocial functioning and captures an important component of sleep health (16,25). However, it is essential to recognize that there are other important sleep indicators to consider that were not measured in the current study. These include sleep quality (e.g., efficiency, continuity), schedule (e.g., difference between weekday and weekend), daytime sleepiness, and naps (21,156). Future studies should incorporate additional sleep subjective measures and consider objective sleep measures in support of the importance of establishing and maintaining a good slep during adolescence. Also, the current study pooled different concepts under the term "student pressures", that do not directly assess whether students perceive these factors as stressful. Our evaluation of student pressures was not based on a validated measure of student pressures, but rather, relied on a PCA of school-related items from the COMPASS survey. We recognize that students may not experience the academic

variables (i.e., homework time, perceptions of the importance of good grades, and academic expectations) and parental expectations as distressing.

Lastly, all data were self-reported. Previous adolescent sleep studies that have utilized self-reported survey data suggests that it may not provide a complete representation of sleep on the outcome measure of interest (157). However, self-report measures are common practice to feasibly obtain data in this large of a sample size and school-based research, and an important way to investigate individuals' perceptions of their sleep duration, which was the variable of interest in this study (134). A concern with using self-report data is that participants may provide responses that are socially desirable (85). Future research could examine whether the same patterns of co-occurrence that were found throughout this study still result when using objective measures (actigraphy) of sleep duration and quality.

Future studies should also consider including more timepoints to allow a more comprehensive investigation of the reciprocal nature between sleep duration and internalizing symptoms at the high school level. The minimum fitting for a longitudinal study assessing mediation is three waves of data, but it has been suggested that this is not enough (158). Additionally, having more time points using allows for more opportunities to reproduce findings (159), and can be especially beneficial if there is a difference between the variables of interest over time. However, a major strength of this study, given that existing research is primarily cross-sectional, is the large sample and prospective data, allowing temporality to be established in the relationships to be studied. Lastly, the COMPASS study was not designed to be provincially or nationally representative; however, the full school samples and high annual response rates (over 80%) support generalizability.

5.4. Conclusion

Inadequate sleep is a problem that has been afforded little recognition, despite known declines over adolescence, a critical period for the onset of mental ill-health. This work provides new insights into the nature and directionality of associations between sleep, student and parent-related stressors, and internalizing symptoms over time. Results will help inform universal population-level approaches for mental health promotion and targeted mental illness prevention. Interventions promoting regular sleep schedules in adolescence may help mitigate risk for stress-related psychopathology. It is important for school administrators and public health authorities to understand the impact of the school and family environment in order to create successful interventions for insufficient sleep and the prevention of mental ill-health. Overall, results were stronger for females than males. Future studies should continue to investigate these relationships using prospective designs over longer periods and objective measures for sleep. Further research is also warranted to evaluate the role of sleep-related problems within the context of other risk factors, such as disordered eating and behaviors such as social and family functioning. Parents and educators need to know that adolescents' tendency to go to bed and wake up later is normal, and this must be considered in addressing sleep habits in the context of adolescent development. Bringing these findings together, these results highlight the importance of interventions targeting inadequate sleep in adolescence, as these may prove effective for the prevention of long-term psychological difficulties.

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