Exploring the Association between Income Inequality and Sleep in Canadian Teens

by

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A thesis submitted in partial fulfillment of the requirements for the degree of

Master of Science

in

Epidemiology

School of Public Health
University of Alberta

Abstract

Background: Sleep deprivation is a substantial public health concern with 30% of Canadian adolescents not getting the recommended eight to ten hours of sleep. In addition to individual level risk factors for teen sleep deprivation such as increased use of electronic devices and greater sedentary time, according to the Social Determinants of Health Framework, characteristics of the social environment may play a role in sleep. One such characteristic is income inequality, the gap between rich and poor within a society. Existing research has found an association between income inequality and sleep among adults, especially women. However, no prior study has examined the role of income inequality in adolescence. Considering the prevalence of sleep deprivation among teens and income inequality in Canada, describing the association between income inequality and sleep deprivation is of paramount importance.

Objective: The aim of my thesis was to examine the association between income inequality and sleep duration among Canadian adolescents, how depression, anxiety and social cohesion mediate this relationship, and how these associations differ by gender.

Methods: Using cross-sectional data of 74,501 secondary school students from wave 7 (year 2018-2019) of the Cohort on Obesity, Marijuana use, Physical activity, Alcohol use, Smoking, and Sedentary behavior (COMPASS) study, multilevel modelling analysis and multilevel path analysis were conducted. Income inequality (Gini index) was measured at the census division level and self-reported sleep duration, gender, depression (measured using the CESD), anxiety (measured using the GAD7), and social cohesion (operationalized as school connectedness) were measured at the individual level.

Results: Greater income inequality (Gini index) was associated with lower sleep duration (β=-3.65 minutes sleep per 1% increase in income inequality, p<0.001, 95% CI=-5.63 to -1.68) and increased odds of short sleep (<8 hours) vs. normal sleep (8-10 hours) (OR=1.08, p<0.001, 95% CI=1.04 to 1.13). The cross-level interactions between income and gender were significant, suggesting that the income inequality has more adverse effects on the sleep of females than males. A full mediation effect of depression (β=-3.09, p=0.003, 95% CI=-5.15 to -1.03) and anxiety (β=-3.64, p=0.001, 95% CI=-5.88 to -1.41) wherein greater income inequality was associated with higher levels of depression and anxiety, which were in turn, associated with a shorter sleep duration was also found. The mediation effect of depression was slightly stronger in males than females and the mediation effect of anxiety was stronger

in females than males. Moreover, a full mediation effect of social cohesion, wherein greater income inequality was associated with a lower level of social cohesion, which was in turn, associated with a shorter sleep duration, was observed in both the female and male stratified samples (with a stronger effect in the former), but not in the whole sample.

Conclusion: The results provide further reasoning for policy makers to focus on decreasing income inequality to improve the health of society members, such as through progressive taxation policies. Findings suggest that reducing societal income gaps may improve adolescent sleep especially in those attending school in high income inequality areas, females, and those experiencing depression and anxiety. This research also highlights the need for tailored approaches to improving adolescent sleep. Greater investment and research in school-based sleep health promotion should be done in areas with greater income inequality.

Preface

This thesis is an original work by Priya Patel under the supervision of Dr. Roman Pabayo and thesis committee member Dr. Kate Storey. The research project, of which this thesis is a part, received research ethics approval from the University of Alberta Research Ethics Board. Chapter 4 of this thesis used data from COMPASS, as such, TriCouncil Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2) certification requirements were completed to access and disseminate the COMPASS data. The current study was approved by the University of Alberta IRB (ORE 00040729), the University of Waterloo Research Ethics Board (ORE 30118), Brock University (REB#18-099), CIUSSS de la Capitale Nationale–Université Laval (#MP-13-2017-1264), and participating school boards.

This thesis has not been previously published. Chapter 4 of this thesis will be adapted and submitted to a journal in collaboration with Drs. Kate Storey, Karen Patte, Scott Leatherdale, and Roman Pabayo.

Acknowledgements

A big thank you to my supervisor, Dr. Roman Pabayo, for your unwavering mentorship, guidance, and kindness these past two years. Roman, your expertise in and passion for social epidemiology is inspiring. Thank you for always encouraging me to challenge myself as a public health student, researcher, and person. I am so grateful to have been part of and learned from the wonderful community you have cultivated with the EMERGE Lab.

Thank you to my EMERGE buddies for all your support. A special thanks to Urvi for all your STATA expertise!

Thank you to my committee member, Dr. Kate Storey, for your generous feedback and mentorship. I am grateful to have had the opportunity to work with you. Thank you as well to my external examiner, Dr. Yan Yuan, for your helpful feedback.

I would like to acknowledge the Cohort study on Obesity, Marijuana use, Physical activity, Alcohol use, Smoking and Sedentary behaviour (COMPASS) study participants, families, staff, and principal investigators Dr. Scott Leatherdale and Dr. Karen Patte.

I would also like to acknowledge the Canadian Institutes of Health Research, the University of Alberta's School of Public Health, and Faculty of Graduate Studies and Research for their financial support throughout this program.

A big thank you to my dear family and friends for their constant support through this journey. To my mom, dad, and little bro, your unconditional love and encouragement has been invaluable. Thank you for continually demonstrating the importance of hard work and perseverance. To my friends, thank you for all your curiosity and questions about my thesis and for ensuring I made time for self-care. And finally, thank you Devi, for always supporting and encouraging me to follow my dreams.

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Chapter 1: Introduction

1.1 Theories of sleep and measurement

Like breathing, drinking water, and eating, sleeping is an essential function throughout the life course. Humans, on average, spend a third of their lives sleeping[1]. While it is well established that sleep is a basic human need, its precise role has not been fully understood[2]. Notable theories explaining the purpose of sleep include the inactivity theory, restorative theory, and the brain plasticity theory. The inactivity theory posits that sleeping at night is an adaptation that improves survival[2]. As animals have increased vulnerability at night given the lack of visibility, animals who were inactive and quiet at night were less likely to die from predators or accidents than those who remained awake. With natural selection, this behaviour evolved into sleep[2]. The restorative theory suggests that sleep is a time for restoration and repair of cellular components that are consumed during times of wakefulness[3]. This theory is supported by the fact that many repair and restorative activities such as protein synthesis, cell division, and release of growth hormone mainly occur during sleep. The brain plasticity theory states that sleep allows for the brain functional and structural organization and development[2].

Sleep can be described by subjective measures of quality, or quantitatively through sleep duration. Canada's 24-hour movement guidelines have the following age-specific sleep duration recommendations: 14 to 17 hours of sleep per night for those aged 0-3 months[4], 12 to 16 hours for those aged 4-11 months[4], 11 to 14 hours for those aged 1-2 years[4], 10 to 13 hours for those aged 3-4 years[4], 9-11 hours for those aged 5-13 years[5], 8 to 10 hours for those aged 14-17 years[5], 7 to 9 hours for those aged 18 to 64 years[6], and 7 to 8 hours for those aged 65+ years[6]. They also have sleep hygiene recommendations such as uninterrupted sleep and consistent sleep and wake times. These guidelines largely overlap with those published by the USA's National Sleep Foundation[7]. Children and youth require more sleep than adults as they are still growing and sleep plays a major role in for physical, emotional, and social development[4].

1.2 Sleep deprivation as a public health problem

Sleep deprivation, the inability to obtain the recommended quantity or quality of sleep, affects people across all age groups and is often recognized as a public health epidemic[8]. In a survey of adults in

12 countries, 62% of participants reported not sleeping as well as they'd like. Moreover, 44% reported a decrease in quality sleep over the past five years[9]. Per the Statistics Canada General Social Survey, only 40% of Canadians 15 years of age and older, reported 7 to 9 hours of good quality sleep per night[10].

According to the Canadian Health Measures Survey, a population-based-representative study, 30% of Canadian teens do not get the recommended amount of sleep[11]. A longitudinal study of Canadian students in grades 9 to 12 found that the sleep durations of Canadian adolescents decline as they grow older[12], suggesting that this pattern may continue and that sleep deprivation in teen years may persist into adulthood.

1.3 Consequences of teen sleep deprivation

Short-term sleep deprivation among teens has been linked to fatigue, car accidents due to impaired coordination, increased risk taking behaviour such as unprotected sex and illicit substance use, and poorer academic performance due to lower memory and attention[13]. Chronic sleep deprivation intensifies the effects of short term sleep deprivation and increases the likelihood of mental illness such as depression and anxiety[14,15] and chronic diseases such as diabetes, heart disease, obesity, and cancer, all of which contribute to increased mortality and morbidity[16,17] and exert a significant financial toll on Canada's healthcare system. Every year, lost working hours attributed to sleep deprivation are estimated to cost the Canadian economy $21.4 billion[18].

1.4 Individual level risk factors for teen sleep deprivation

Several biological and social factors contribute to increased susceptibility to sleep deprivation in adolescence. Adolescence marks the beginning of sleep phase delay, wherein the body's circadian rhythm naturally shifts 1-2 hours forward[19], as well as later melatonin release, leading to delayed sleep onset[12]. Adolescence is also a time of increased independence, lower parental supervision, and busier schedules with greater schoolwork and extra-curricular and social commitments, serving as potential barriers to sleep[12].

Evidence suggests that certain demographic groups, such as girls and Asian adolescents, and adolescents living in urban areas, disproportionately experience sleep deprivation[12].The main predictors and covariates of sleep deprivation among adolescents are described in Table 1.

Table 1. Summary of individual-level predictors and covariates of teen sleep deprivation

Predictor	Description
Gender	Female teens tend to obtain less sleep than male teens[20–22].
Age	Older adolescents are more likely to be sleep deprived than younger adolescents[11].
Race	The risk of sleep deprivation is greater among Asian teens, relative to white teens[12].
Screen use	Increased use of electronic devices, especially in the evening, is associated with lower sleep quality and duration among teens[23].
Physical activity	Among adolescents, increased sedentary time is associated with lowered sleep duration while increased physical activity is associated with increased sleep duration[24,25].
Eating behaviour	Teens who consume more fast food and caffeinated beverages and fewer healthful foods such as vegetables and fruits are more prone to sleep deprivation[26–28].
Body mass index	Greater BMI has been associated with lower sleep duration[29].
Mental health conditions	Adolescents with depression are at increased risk of sleep deprivation than those without depression[30].
Sleep disorders	Sleep deprivation is a common symptom of sleep disorders such as insomnia and sleep apnea[31].

1.5 Brief overview of social determinants of health framework and income inequality

While these are individual-level predictors of teen sleep deprivation, the social determinants of health (SDOH) framework posits that the non-medical contextual conditions in which people are born, grow, live, and age, play an important role in health outcomes[32]. These characteristics are influenced by the dispersion of power, and resources on a global, national, and local scale. One such characteristic, income inequality - the gap between rich and poor or unequal distribution of incomes in a society, has been linked to adverse health outcomes[33].

To my knowledge, only two studies have examined the association between income inequality and sleep. Studies from Mexico and USA suggest an association between greater income inequality and lower sleep duration and quality, among adults[34,35].

1.6 Study aim and objectives

No prior study has examined the association between income inequality and sleep in adolescents or in a Canadian setting. Income inequality and sleep deprivation have both been on the rise in Canada.

Several biological and social factors contribute to increased susceptibility to sleep deprivation in adolescence. Moreover, income inequality experienced in childhood has been shown to have a greater adverse impact on health than that experienced in adulthood[36]. Therefore, it is of critical importance to examine the association between income inequality and sleep in this demographic group.

The present study will address gaps and limitations in and add to the literature through a cross-sectional analysis of pan-Canadian data collected during wave 7 (years 2018-2019) of the Cohort study on Obesity, Marijuana use, Physical activity, Alcohol use, Smoking and Sedentary behaviour (COMPASS) study[37]. COMPASS is prospective longitudinal study (2012-present), with the primary objective of examining the associations between government policies, school environment and youth health behaviors such as diet, substance use, mental health, and physical activity[37]. COMPASS is comprised of annual data from teens attending secondary schools across Ontario, Alberta, Quebec, British Columbia, and Nunavut. The proposed study has the following objectives:

(1) Summarizing and synthesizing existing literature on the association between area-level absolute and relative income inequality measures and sleep through a narrative review, to provide context for the analyses.

(2) Examining the association between income inequality and sleep duration among Canadian adolescents and how this association varies across gender, using multilevel modeling analysis

(3) Assessing how depression, anxiety and social cohesion mediate the relationship between income inequality and sleep duration among Canadian adolescents and how this association varies across gender, using multilevel path analysis

By elucidating the link between income inequality and teen sleep deprivation, this work may motivate policy makers to implement policies to reduce income inequality and inform school-based interventions to support adequate sleep during this critical developmental stage. This research may also identify certain subgroups toward whom such efforts should be targeted. Fostering healthy sleep behavior in adolescence will set the course for improved lifetime health and ultimately, reduce the chronic disease burden in Canada.

Chapter 2: Background

2.1 Social determinants of health framework

The SDOH framework posits that characteristics of the social environment influence the health of individuals and populations throughout the life course. These characteristics may include pollution, noise, social fragmentation, and socioeconomic status (SES) and have been shown to be stronger predictors of health outcomes than medical care or lifestyle choices[32].

A systematic review of 22 articles found an overall association between greater exposure to air pollution (e.g., nitrogen dioxide, ozone, combustion products) and decreased sleep health (with outcomes such as sleep quality and duration), across different nations and age groups[38]. In a study of 10,123 American teens, those living in neighbourhoods with the highest level of outdoor artificial light at night reported 11 fewer minutes of sleep than those in neighbourhoods with the lowest level of outdoor artificial light at night[39]. A study of 110 American teens found an association between greater neighborhood noise and decreased odds of obtaining ≥8 hours of sleep per night (odds ratio OR=0.75, 95% CI=0.59 to 0.96)[40]. Another American study found an association between high neighbourhood social fragmentation and reduced odds of obtaining adequate sleep among teens (OR=0.33, 95% CI=0.18 to 0.61)[41].

2.2 Income

Income is a well-documented social determinant of health and a form of absolute income inequality. Higher income, at both the individual/family and area (e.g., neighbourhood) level, has been consistently associated with better health outcomes and fewer health risks[42]. While the average Canadian household income has increased over the years, it has fallen short of the rise in inflation. In 2021, increases in wages were below increases in inflation across all provinces by 1.5%, on average[43].

Most of the existing literature suggests an association between greater individual/family level income and greater sleep duration and quality. For example, Roberts at al. examined 4175 American teens aged 11 to 17 years and found an association between lower family income and greater likelihood of sleep disorder[44]. Another study with 247 American teens aged 13 to 16 found an association between greater parental income and greater sleep duration[45]. Depression and family chaos, such as lack of daily routine or greater levels of sensory disruptions (e.g., arguments between family members), have been examined as mediators of the association between individual level income and sleep[46].

Most of the existing literature on area level income and sleep looks at area level socioeconomic status and sleep. Socioeconomic status includes factors such as proportion of households with income below poverty level, proportion of households without motor vehicles, proportion of housing units that are owner occupied, and proportion of households receiving social assistance in addition to income. Most studies on this topic point to an association between greater area level socioeconomic status and greater sleep duration and quality. For example, a study examining a sample of approximately 400 Australian teens aged 10 to 15, found a decline in sleep duration from years 1985 to 2004 among both girls (561.9±97.8 min to 492.9±89.2 min, p≤0.001) and boys (535.3±86.1 min to 486.0±104.3 min, p≤0.01) living with low neighbourhood SES, classified using economic resources, education, and occupation of householders[47]. Another study with a sample of 210 American youth with a mean age of 11.3±0.63 years observed an association between greater neighbourhood economic deprivation (determined using % of individuals receiving public assistance, median household income, and % of residents in poverty) and lower sleep duration (β=–15.01, p=0.004). Limited research exists on the mechanisms of association between area level income and sleep[48].

2.3. Income inequality

Another, albeit less studied area-level social determinant of health is income inequality, the unequal distribution of incomes in society[33]. Growing literature suggests an association between income inequality and increased risk of adverse health outcomes including depression, anxiety, and heart disease, independent of absolute income[49,50]. That is to say, income inequality appears to be a predictor of health for individuals with varying levels of absolute incomes[51].

Income inequality can be classified as absolute income inequality, the absolute income difference in money terms, and relative income inequality, the disproportionality of income distributions. The difference between these two concepts can be illustrated using an adapted example from Goda[52]: Say individual A has an income of $1 and individual B has an income of $10. Individual B has a greater income than individual A in an absolute sense (9$ more) and relative sense (10 times greater)[52]. If the income of both individuals increases by $5 (individual A=$6 and individual B=$15), the relative income gap decreases from 10 times greater to 2.5 times greater while the absolute difference of $9 stays the same. If the income of both individuals increases by 10% (individual A=$1.1 and individual B=$11), the

absolute income gap increases from $9 to $9.9 while the relative income gap of 10 times greater stays the same[52]. In this thesis, income inequality refers to relative income inequality[52].

In public health research, income inequality is usually assessed using the Gini index. This measure ranges from 0 (theoretical condition of perfect distribution of income in a society) to 1 (theoretical condition of perfect inequality wherein one individual has all the income in a society)[53]. Using the Lorenz curve shown in Figure 1[53], the Gini index can be calculated by dividing the area between the perfect equality line and the Lorenz curve (A) by the total area under the perfect equality line (A + B). The smaller area A, the more equal the distribution of income and vice versa[53]. Advantages of Gini index measure include ease of calculation and interpretation and independence of population and economy size, allowing for comparison between diverse societies[54]. One drawback of this measure is that it fails to provide information on the pattern of income distribution. For instance, a Gini index of ½ would be ascribed to both a society with half of its residents having zero income and the other half sharing total income equally and a society with all but one resident sharing half the total income equally and one resident having the remaining half to themselves[54].

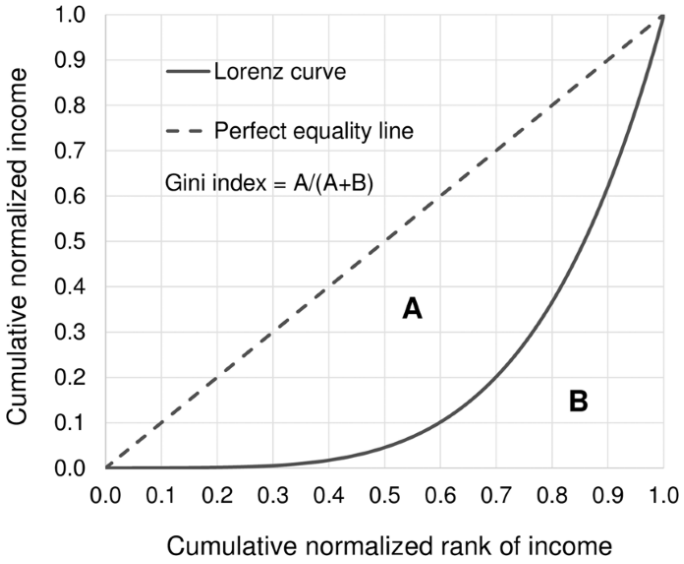

Figure 1. The Lorenz curve for Gini index calculation [53]

Other measures of income inequality include the Theil index, measuring an entropic "distance" between the population and the "ideal" egalitarian condition of perfectly equal distribution of income, with greater values alluding to higher income inequality. The Atkinson index is the proportion of total income

that would be required to attain equal social welfare if incomes were equally distributed[55]. The Robin Hood index measures the proportion of income that must be transferred from those with above average income to those below the average income in a society to achieve an equal distribution. Both the Atkinson index and Robin Hood index range from 0, representing perfectly equal distribution of income to 1, representing perfectly unequal distribution of income[55].

Kawachi and Kennedy compared the health effects of the aforementioned measures of income inequality and found high correlation (r=0.86 to 0.99) between the different measures[56].

2.3.1 Trends in income inequality

Income inequality can be assessed at several different levels such as global, national[57], census division, municipal, or neighbourhood levels. Global income inequality, often measured by comparing average gross domestic product per capita between nations, continues to be substantial. For instance, the mean income of people in Sub-Saharan Africa is 16 times lower than that of people in North America[58]. However, overall inter-country income inequality has decreased in the past two decades as the mean incomes of those in developing nations have been growing at a faster rate than those of people in developed nations. This trend may be attributed to the rapid growth of emerging economies such as China and India[59].

National level income inequality is a comparison of differences in gross incomes between individuals and households within a country. Unlike overall inter-country income inequality, intra-country income inequality has been increasing in many countries[59,60].

Income inequality in Canada reduced in the 1980s, increased in the 1990s, but has remained relatively stable in the 2000s[60]. The increase in income inequality was largely driven by greater increases in the incomes of those on the higher end of the income spectrum than those on the lower end. The richest 1% of Canadians made approximately $180,000 more in 2010 than they did in 1982 (adjusted for inflation), while the bottom 90% of Canadians made gains of only $1,700 during this time period[61].

Income inequality in most Canadian provinces increased over the 1980s and 1990s and stabilized during the 2000s. However, in Alberta the Gini index increased from 0.294 in the 1980s to 0.319 in 2014. Income inequality declined from the 1980s to 2014 to levels below the 1970s in New Brunswick (0.281 to 0.277) and Quebec (0.284 to 0.281)[62]. Of the provinces, Nunavut (Gini index=0.33)

and Ontario (0.31) have the highest income inequality while Prince Edward Island (0.27) and New Brunswick (0.27) have the lowest income inequality[63].

Income inequality increased in most of Canada's major cities between years 1980 to 2005, such as in Calgary (Gini index=0.107 to 0.194) Toronto (0.128 to 0.063), Winnipeg (0.106 to 0.154), and Edmonton (0.092 to 0.132). As of 2021, Toronto (0.330), Calgary (0.327), and Vancouver (0.321) have the highest income inequalities while Québec (0.257), Drummondville (0.256), and Saguenay (0.254) have the lowest[64].

Population-level approaches for mitigating income inequality include progressive taxation, wherein those with higher incomes have higher tax rates. An analysis of historical data in the United States from 1962 to 2014 showed an association between periods of progressive taxation and lower income inequality as well and improved mental health[65]. Increasing minimum wage has also been shown to lower income inequality[66].

2.3.2 Possible mechanisms linking income inequality and sleep

One potential mechanism through which income inequality may influence sleep is through the social comparison theory which states individuals base their social and personal worth based on how they compare with others[67]. Increasing income inequality may intensify feelings of worthlessness and insecurity among those members of the community who feel that they have been "left behind"[68]. This may contribute to the association between income inequality and depression and anxiety[69], common risk factors for sleep deprivation[30].

The effects of income inequality on sleep may also be mediated by lower investment in public goods such mental health services, which is associated with increased risk of adverse mental health outcomes. Adverse mental health outcomes such as depression and anxiety has been linked to lower sleep duration.

Another possible mechanism involves social cohesion, the degree of connectedness among groups and people in society. Income inequality has been shown to decrease social cohesion[70], which can in turn increase the risk of mental health conditions such as depression and anxiety[33,71].

Chapter 3: Literature review

3.1 Overview

The following chapter of this thesis is a narrative review to summarize and synthesize existing literature on the quantitative association between area-level absolute and relative income inequality measures and sleep. This review identified limitations and gaps in the existing literature and provided context for the thesis analyses. This review was not limited to studies on relative income inequality and sleep and included area level absolute income inequality (e.g., neighbourhood SES), given the dearth of literature on the former, as evident in the preliminary review.

3.2 Methods

3.2.1 Inclusion criteria

Articles that met the following a priori determined inclusion criteria were included:

Study type: Peer reviewed cross-sectional/cohort/case-control studies

Participant characteristics: Human participants of any age, gender, gender, ethnicity(ies), recruited from any setting

Exposure type: area- (e.g., neighbourhood-/census division-/municipal-) level absolute or relative income inequality

Outcome type: sleep duration or sleep quality

Language: Any

Publication date: Any

3.2.2 Search Strategy

Four databases (PubMed, Scopus, CINAHL, and PsycINFO) were searched from inception to May 31st, 2023. A search strategy was developed in PubMed, with the aid of a subject librarian. I adapted this search syntax for each of the other three databases. Full search strategies for each database can be found in the Appendix.

3.2.3 Study Selection

All retrieved articles were moved into Covidence (Covidence, Melbourne, Australia) for duplicate removal and screening. A twofold screening process was implemented: 1. Title and abstract screening. 2.

Full text screening of articles that passed the title and abstract screening. I completed both screening steps using the inclusion criteria described in 3.2.1.

3.2.4 Data Items and Collection Process

A data extraction form was created with the following headings: authors, year of publication, region/city, state, country, study design, sample size, %female, mean (SD) age or age range, ethnicity/race, neighbourhood SES/income inequality exposure construct, assessment, source, sleep outcome construct, assessment, model type, individual-level covariates, area-level covariates, main findings. Findings were narratively synthesized.

3.3 Results

3.3.1 Study characteristics

6,161 records were generated by a literature search using PubMed, Scopus, CINAHL, and PsycINFO. 1123 duplicates were removed, 5,038 articles were screened at the title and abstract level and 43 articles underwent full-text screening. 15 articles were excluded at the full-text level, leaving 28 to be included in the preliminary review (Table 2). Given the dearth of studies on income inequality and sleep identified by the literature search, an additional 2 articles were handpicked from Google Scholar and included in the review (for a total of 30 articles). Studies were based out of a total of 8 countries (18 from the USA, 4 from Australia, 4 from Canada, 1 from Sweden, 1 from Britain, 1 from Netherlands, 1 from Mexico). 28 studies utilized a cross-sectional study design while 2[72] used a longitudinal cohort design. Sample sizes of the included studies ranged from 80[73] to 350,929[74]. 16 studies included an adult sample, 7 included a child sample (mean age between 0 to 12.9), 5 included a teen sample (mean age between 13 to 17.9) and 1 included a child and teen sample[47]. Gender distribution ranged from 43.8%[73] female to 85.1%[75] female.

Table 2. Literature review of articles on sleep and area-level absolute or relative income inequality

Authors, Year **Region/city, state country** **Study design**	**Sample size** **%female** **Mean (SD) age or age range** **ethnicity/race**	**Neighborhood SES/income inequality exposure Construct** **Assessment** **Source**	**Sleep outcome Construct** **Assessment**	**Model description** **Individual-level covariates** **Area-level covariates**	**Main findings**
Li et al., 2022[76] Calgary, Canada Longitudinal	n=2444 50.7% female Age=12 months 76.8% European Canadian, 13.1% Asian Canadian, 2.3% Latinx Canadian, 1.5% African Canadian, 1.5% Arab Canadian, 0.8% Indigenous, 3.6% Mixed/Other Community dwelling	**Construct:** neighbourhood deprivation **Assessment:** Vancouver Area Neighborhood Deprivation Index (VANDIX) calculated using census tract indicators such as income, education, employment, single-parent households Census tract indicators geocoded to home addresses **Source:** 2011 National Household Survey, accessed through the Calgary Community Data Consortium higher scores=greater deprivation	**Construct:** sleep duration **Assessment:** parent-reported number of hours baby usually sleep at night	**Model:** multilevel modeling **Individual level covariates:** Maternal race/ethnicity, maternal education, household income, family history of language delay, infant sex, preterm birth, vocabulary **Area level covariates:** neighbourhood disorder	Neighbourhood deprivation not statistically significantly associated with sleep duration (β=1.26 hours sleep per 1 unit increase in neighbourhood deprivation, p=0.054, 95%CI=−0.023 to 2.542)

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Bagley et al., 2018[48] small towns and semi-rural communities in Alabama, USA Cross-sectional	n=210 45.7% female Mean age=11.3 years SD age=0.63 years 66.7% European American, 33.3% African American Community dwelling	**Construct:** neighborhood economic deprivation **Assessment:** census tract indicators of % of individuals receiving public assistance, median household income (reverse coded), and % of residents in poverty Census tract indicators geocoded to home addresses **Source:** Neighborhood census tract indicators derived from the 2012 American Community Survey, conducted by the U.S. Census Bureau	**Construct:** sleep duration **Assessment:** actigraphy-determined sleep minutes, measured for 5-7 consecutive nights (number of minutes *scored as sleep* between sleep onset and wake time)	**Model:** multilevel modeling **Individual level covariates:** age, sex, race, cohabitation, income-to-needs ratio, pubertal status, chronic conditions, BMI **Area level covariates:** neighborhood social fragmentation, neighborhood economic deprivation	Neighborhood social fragmentation, neighborhood economic deprivation entered separately: neighborhood economic deprivation associated with lower sleep minutes (β=–13.47 sleep minutes per 1 unit increase in neighborhood economic deprivation, SE=5.04, p=.008) Entered together, neighborhood economic deprivation associated with lower sleep minutes (β=–15.01 sleep minutes per 1 unit increase in neighborhood economic deprivation, SE=5.22, p=0.004)

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Zhu et al., 2019[77] Netherlands cross-sectional	n=77,244 58.6% female Mean age=46 Age range=40 to 53 years Community dwelling	**Construct:** neighbourhood socio-economic disadvantage **Assessment:** PCA of: % of the population with the highest 20% income, % of the population with the lowest 20% income and % of the population receiving social benefits. Categorized into quintiles (group 5=most neighbourhood socio-economic disadvantage) **Source:** data derived from the Neighbourhood Statistics (year 2011) of Statistics Netherlands (CBS)	**Construct:** sleep duration **Assessment:** self-report Dichotomized into >=7 or ≤9 h sleep vs. <7 or >9 h sleep	**Model:** generalized linear mixed regression **Individual level covariates:** age, sex, BMI	Greater odds of <7 or >9 h sleep for those in the 5th NSED group compared to those in 1st NSED group (OR=1.19, 95% CI=1.11 to 1.28) No statistically significant differences in odds of <7 or >9 h sleep between 4th NSED group and 1st NSED group, (OR=1.06, 95%CI=0.99 to 1.14), and between 3rd NSED group and 1st NSED group (OR=1.00, 95%CI=0.93 to 1.07) Non statistically significantly lower odds <7 or >9 h sleep for those in the 2nd NSED group compared to those in 1st NSED group (OR=.96, 95%CI=0.89 to 1.03)

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Rassu et al., 2021[78] Salt Lake City, Utah and Baltimore, Maryland in USA Cross-sectional	n=97 70.7% female Mean age=48.5 years SD age=11.8 years 54.5% white, 36.4% black, 3% other race, 2% Asian, 2% multiracial People with confirmed chronic lower back pain actively seeking professional healthcare	**Construct:** neighborhood deprivation **Assessment:** area deprivation index (ADI) derived from 17 social and material deprivation metrics (e.g., poverty, education, employment, housing-quality) ADI linked to home addresses categorized into low (range 2–32), moderate (range 36–65), and high (range 67–100 or most neighborhood deprivation)	**Construct:** changes in sleep quality from before to during COVID-19 pandemic **Assessment:** self-report Likert scale: “Very much improved,” “Much improved,” “Minimally improved,” “No change,” “Minimally worse,” “Much worse,” and “Very much worse” Categorized into tertiles (1=“very much improved” and “much improved”; “minimally improved or no change or minimally worse”; “much worse or very much worse”)	**Model:** Trend test	No statistically significant differences in changes in sleep quality between 3 neighbourhood deprivation levels (p=0.161): Very much improved or much improved sleep quality: 9.5% in low, 6.3% in moderate, 13.6% in high neighbourhood deprivation Minimally improved or no change or minimally worsened sleep quality: 76.2% in low ADI, 59.4% in moderate ADI, 54.5% in high ADI sleep quality change category Much worse or very much worsened sleep quality: 14.3% in low ADI, 34.4% in moderate ADI, 31.8% in high ADI

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Raza et al., 2021[72] Sweden Repeated measures/longitudinal	n=12,932 57% women Mean age=50 years Age range=20-75 years Community dwelling	**Construct:** home neighborhood socioeconomic status **Assessment:** mean household income, % of adults above 18 years with only elementary school education, % of unemployment within 500 and 1,000 m radius of home address Categorized into quartiles (4th quartile=highest home neighbourhood SES) **Construct:** work neighbourhood socioeconomic status **Assessment:** mean household income, low education (percentage of adults above 18 years with only elementary school education), and unemployment (percentage of unemployment) within 500 and 1,000 m radius of workplace address Categorized into quartiles (4th quartile=highest work neighborhood SES) **Source:** Statistics Sweden	**Construct:** disturbed sleep **Assessment:** self-report using Disturbed Sleep Index from the Karolinska Sleep Questionnaire: difficulties falling asleep, restless sleep, repeated nocturnal awakenings, and premature awakening Responses for each question: never, rarely, few times per month, 1–2 times per week, 3–4 times per week, and 5 or more times per week Dichotomized into disturbed sleep (having 1(+) of above problems 3–4 times a week or more) vs. no disturbed sleep	**Model:** fixed-effects approach (also known as within-individual/ case-crossover design) and conditional logistics regression **Individual level covariates:** age, occupational position, marital status, presence of children under 12, chronic disease, depressive symptoms, job strain	No statistically significant differences in odds of disturbed sleep between second quartile home neighbourhood SES and first quartile (OR=0.96; 95% CI=0.78 to 1.20), third quartile and first quartile (OR=1.00; 05% CI=0.76 to 1.30), and fourth quartile and first quartile (OR=0.94; 95% CI=0.68 to 1.30) No statistically significant differences in odds of disturbed sleep between second quartile work neighbourhood SES and first quartile (OR=0.92; 95%CI=0.75 to 1.12), third quartile and first quartile (OR=0.97; 95% CI=0.76 to 1.23), and fourth quartile and first quartile (OR=1.06; 95% CI=0.78 to 1.40)

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Aggarwal et al., 2003[79] South-East Cheshire (Borough of Congleton, Northwest England), Britain Cross-sectional	n=2504 55.31% female Age range=18 to 65 years Community dwelling	**Construct:** deprivation **Assessment:** Townsend index based on % of residents' unemployed, overcrowded households, households without a car and non-home ownership enumeration districts (each with own Townsend index score) linked to home addresses Categorized into quintiles (5th quintile=most deprived) **Source:** enumeration districts derived from 1991 census data	**Construct:** sleep disturbance **Assessment:** self-report using sleep problems questionnaire: trouble falling asleep, waking up several times per night, trouble staying asleep (including waking far too early), waking up after your usual amount of sleep feeling tired and worn out Responses for each question: not at all (0), 1-3 days (1), 4-7 days (2), 8-14 days (3), 15-21 days (4), 22-31 days (5) Sleep disturbance calculated as sum of scores from 4 responses	**Model:** Chi-square test	No statistically significant differences in sleep disturbance between deprivation quintiles (all between 20% to 32%, p=0.122)

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Street et al., 2018[80] Boston, Massachusetts, USA cross-sectional	n=1614 54.2% female Mean age=16.7 years Age range=14 to 19 years 42.8% black, 33.1% Hispanic, 8.9% white, 8.1% Asian, 7.1% other Community dwelling	**Construct:** Neighborhood poverty **Assessment:** PCA of: % of persons living below federal poverty line, % of residents 16 years or older unemployed, % of households on public assistance **Source:** American Community Survey Census (ACS)	**Construct:** sleep duration **Assessment:** self-report using Sleep Timing Questionnaire: typical bedtime and typical wake up	**Model:** multilevel modeling **Individual level covariates:** age, sex, race, hours of homework, positive peer influence, positive parental influence, frequency of family dinners **Area-level covariates:** adjusting for neighbourhood and school clustering	neighborhood poverty associated with greater sleep duration (β=0.10 hours sleep per 1 unit increase in neighborhood poverty, p=0.009)

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Lukic et al., 2021[81] 12 neighborhoods in Calgary, Alberta, Canada cross-sectional	n=797 62.9% female Mean age=51.4 years SD age=13.7 years 88.2% white, 11.8% non-white Community dwelling	**Construct:** neighborhood socioeconomic status **Assessment:** neighborhood SES quartiles based on % of 25–64-year-olds whose highest educational level was below a high school diploma; % of single-parent families; % of rented private dwellings; % of individuals divorced, separated, or widowed among those ≥15 years of age; % of individuals unemployed among those ≥25 years of age; median gross household income; and average value of dwellings Dichotomized into high and low SES **Source:** 2006 Canadian census	**Construct:** sleep duration (continuous) **Assessment:** self-reported hours/minutes of sleep over an average 24 h period **Construct:** sleep duration (categorical) **Assessment:** sleep duration categorized as <7 h per day, 7 to 8 h per day, >8 h per day.	**Model 1:** linear regression **Individual-level covariates:** age, sex, race/ethnicity, marital status, number of dependents under 18 years living at home, main employment activity, hours of work per week, highest level of education attained, annual gross household income, type of survey completed, daily total physical activity, residential relocation **Area level covariates:** neighbourhood socioeconomic status, neighbourhood street pattern **Model 2:** multinomial logistic regression **Individual level covariates:** same as model 1 **Area level covariates:** same as model 1	**Model 1:** No statistically significant association between neighborhood SES and sleep duration (β=-0.07 hours sleep per 1 unit increase in neighbourhood SES; 95% CI=-0.22 to 0.08) **Model 2:** Non statistically significantly lower odds of <7 of sleep vs. 7-8 hours of sleep in those with low neighbourhood SES compared to those with high neighbourhood SES (OR=0.38; 95% CI=.94 to 2.02) Non statistically significantly greater odds of >8 of sleep vs. 7-8 hours of sleep in those with low neighbourhood SES compared to those with high SES (OR=1.43; 95% CI=.87 to 2.36)

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Grimes et al., 2019[73] North Carolina, USA cross-sectional	n=80 43.8% female age=3 months 100% African American Community dwelling	**Construct:** neighborhood deprivation **Assessment:** composite score calculated by standardizing and summing census tract-specific: % below poverty, %receiving food stamps or SNAP, % with less than a high school diploma, and %of families with a female head-of-household and children under the age of 18. **Source:** 2015 American Community Survey	**Construct:** sleep quality **Assessment:** actigraphy-measured average # of night wakings (>5 minutes) over 7 nights (greater the night wakings=lower sleep quality)	**Model:** multilevel modeling **Individual level covariates:** gender and family sociodemographic risk (Family sociodemographic risk calculated from: single parenthood, less than a high school diploma/GED, 3 or more children in household, income-to-needs ratio < 1.3, age at first childbirth < 19 years) **Area-level covariates:** neighbourhood deprivation	Neighborhood deprivation associated with greater sleep quality (β=0.07 units sleep quality per unit increase in neighborhood deprivation, SE=0.02, p<0.01) Each individual census measure that comprised neighborhood deprivation score independently associated with greater sleep quality (βs=0.021 to 0.028 units sleep quality per unit increase in neighborhood deprivation, p<0.05)

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Hunter et al., 2018[82] USA Cross-sectional	n=8090 57.6% female Mean age=67.5 years SD age=3.4 years 85.7% white Community dwelling	**Construct:** neighbourhood SES **Assessment:** NSES index (produced by the RAND Corporation) calculated using census tract-specific: %of adults aged 25 or older without a high school diploma, %of male unemployment, % of households with income below the poverty line, %of households on public assistance, % of female heads of household and median household income	**Construct:** sleep quality **Assessment:** self-report using questionnaire similar to Women's Health Initiative Insomnia Rating Scale: trouble falling asleep, staying asleep, waking too early, and feeling well rested upon waking. (higher scores=higher sleep quality)	**Model:** multiple logistic regression **Individual level covariates:** age, sex, education level, BMI, Race/ethnicity, h yperten[27]sion, diabetes, stroke, and any heart disease **Area-level covariates:** neighbourhood SES	No statistically significant association between neighborhood SES & sleep quality

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DeSantis et al., 2013[83] New York, NY and Los Angeles, CA, USA cross-sectional	n=1,406 54.77% female Age range=45 years to 84 years Community dwelling	**Construct:** neighborhood SES **Assessment:** factor score calculated using PCA of census tract-specific: median household income, percentage of homes with interest and dividends, median value of owner-occupied housing, %of residents with at least a high school diploma, %of residents with at least a BA degree, and %of residents employed in managerial professions **Source:** US census tract-level data	**Construct:** sleep duration **Assessment:** self-reported usual amount of sleep on weekday/work day Categorized into tertiles for **model 1** (high tertile=longest sleep duration)	**Model 1:** multilevel model with neighbourhood characteristics entered separately and random intercept for each census tract to account for clustering by census tract **Individual level covariates:** age, sex, race/ethnicity, education, income-wealth, depressive symptoms, BMI, diabetes , hypertension **Area-level covariates:** neighbourhood SES **Model 2:** multilevel model with neighbourhood characteristics entered simultaneously and random intercept for each census tract to account for clustering by census tract **Individual level covariates:** same as model 1 **Area-level covariates:** neighbourhood SES, social environment, physical environment **Model 3:** testing effect modification by sex, race, age, site, and SES, entered into model separately, controlling for all the others	**Model 1:** mean difference in sleep associated with 1-standard deviation increase in neighbourhood SES=-0.06 (95% CI=-0.11 to -0.01; p<.05) **Model 2:** no statistically significant mean differences in sleep associated with 1 -standard deviation increase in neighbourhood SES (difference=-0.05; 95% CI=-0.13 to .03) **Model 3:** no statistically significant effect modification by sex, race, age, or site

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Johnson et al., 2015[84] Corpus Christi, Texas, USA cross-sectional	n=760 64% female Mean age=52.9 years 84% Mexican American Catholic churchgoers	**Construct:** neighborhood disadvantage **Assessment:** subject address geocoded to 2010 US Census tracts (proxy for neighborhood of residence); if address not identifiable then zip code used Composite score calculated using: *% of female-headed households with children, % of households with incomes below federal poverty threshold in the last 12 months, % of college-educated adults, % of housing units that are owner occupied* Categorized into lowest, middle, upper tertiles (upper tertile=most neighborhood disadvantage) **Source:** American Community Survey 2011 5-year estimates	**Construct:** sleep duration **Assessment:** self-reported usual amount of sleep per night Categorized into short (≤6h), normal (7h or 8h), and long (>=9h)	**Model:** multinomial logistic regression with random intercepts to account for clustering by church and within pair **Individual level covariates:** age, sex, education, income, employment status, depressive symptoms, BMI, diabetes, hypertension **Area level covariates:** neig hbourhood disadvantage	no statistically significant association between greater neighborhood disadvantage and odds of short sleep duration (OR=0.98; 95%CI=0.83 to 1.16)

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Xiao et al., 2018[85] California, Florida, Louisiana, New Jersey, North Carolina, and Pennsylvania, Atlanta, Georgia, and Detroit, Michigan Cross-sectional	n=208,537 46.94% female Age range=50–71 subject address geocoded to 2010 US Census tracts (proxy for neighborhood of residence); if address not identifiable then zipcode used	**Construct:** neighbourhood SES **Assessment:** Baseline subject addresses geocoded to 1990 and 2000 US Census tracts 1990 and 2000 empirical indices calculated using PCA, stratified by state, of: % total with less than high school education, % total unemployed, % unemployed men, % renter occupied housing units, % housing units vacant, median value of all owner occupied housing units, % household with income below poverty, % female headed HH with dependent children, % households with an income <$22500 or <$30000, % households on public assistance, and % households with no car, % non-Hispanic blacks, % residents 65 and above, and % in same residence since 1985 [1990 census] or 1995 Categorized into quintiles (5th quintile=highest neighborhood SES) change in neighborhood SES=difference b/w 1990 and 2000 percentiles	**Construct:** sleep duration, night **Assessment:** self-reported time spent sleeping at night in typical 24 hours period over past 12 months: “less than 5 hours”, “5 to 6 hours”, “7 to 8 hours” and “9 or more hours”	**Model:** multinomial logistic regression between nightly sleep duration and baseline neighborhood SES **Individual level covariates:** age, race and ethnicity, education, marital status, state of residence, change in neighborhood SES, and napping duration **Area level covariates:** Robust variance estimation used for standard error estimation to account for clustering across census tracts	RRR of <5h nightly sleep duration in women in Q1=1.65 (1.45, 1.89) RRR of 5-6h nightly sleep duration in women in Q1=1.21 (1.15, 1.27) RRR of <5h nightly sleep duration in men in Q1=1.34 (1.16, 1.54) RRR of 5-6h nightly sleep duration in men in Q1=1.07 (1.03, 1.12)

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Bassett et al., 2014[86] Montreal, Quebec, Canada cross-sectional	n=2643 64.81% female Females: 15.5% 25-24 years, 16.8% 35-44 years, 19.6% 45-54 years, 16.3% 55-64 years, 21.1% 65-74 years, 10.8% 75+years Males: 13.4% 25-34 years, 19.5% 35-44 years, 21.5% 45-54 years, 16% 55-64 years, 20.6% 65-74 years, 9% 75+ years	**Construct:** neighbourhood disadvantage **Assessment:** measure calculated using: unemployment rates (0.29), median household income (−0.18), % of immigrants (0.03), % of single mothers (0.07), % of renters (0.50), and the percentage of college educated residents (−0.13) Source: 2006 Canada Census	**Construct:** restless sleep **Assessment:** self-reported presence or absence of restless sleep over the previous week	**Model 1:** Multilevel logistic regression in men only **Individual level covariates:** age, marital status, primary household language, socioeconomic status, network social capital, participation, generalized trust, self-rated health **Area level covariates:** neighbourhood disadvantage, Census tract neighborhood population density **Model 2:** Multilevel logistic regression in women only **Individual level covariates:** age, marital status, primary household language, socioeconomic status, network social capital, participation, generalized trust, self-rated health **Area level covariates:** neighbourhood disadvantage, census tract neighborhood population density	**Model 1:** In men, non-statistically significantly lower odds of restless sleep in those living with neighbourhood disadvantage than no neighborhood disadvantage (OR=0.92, 95%CI=0.72 to 1.17) **Model 4:** In women, greater odds of restless sleep in those living with neighbourhood disadvantage than no neighbourhood disadvantage (OR=1.18, 95%CI=1.01 to 1.38) interaction analysis did not show effect modification by gender

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Mackinnon et al., 2020[87] Calgary, Alberta, Canada Cross-sectional	n=2443 50.6% female 12 months old	**Construct:** neighbourhood deprivation **Assessment:** subject address overlaid on Calgary community districts using ArcGIS Desktop spatial join tool Neighborhoods linked to Statistics Canada 2011 National Household Survey census data Vancouver Area Neighborhood Deprivation Index calculated using Census-based material (income, education, employment) and social (e.g., single parent families) indices **Source:** Statistics Canada 2011 National Household Survey census	**Construct:** sleep duration **Assessment:** maternal reported # of hours in a row baby usually sleeps at night	**Model:** multilevel modeling **Individual level covariates:** infant sex and maternal age, ethnicity, education, and employment status, household income, breastfeeding, and co-sleeping **Area level covariates:** neighbourhood deprivation	neighborhood deprivation associated with lower sleep duration (β=−0.062 hours sleep per unit increase in neighborhood deprivation; p=0.032)

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Nahmod et al., 2022[88] Austin, Baltimore, Boston, Chicago, Corpus Christi, Indianapolis, Jacksonville, Nashville, New York, Norfolk, Philadelphia, Pittsburgh, Richmond, San Antonio, San Jose, and Toledo, USA cross-sectional	n=682 observations=4846 52.3% female Mean age=15.4 years 44.0% black, 25.7% Hispanic/Latino, 16.9% white, 13.5% other	**Construct:** neighbourhood disadvantage **Assessment:** primary caregiver's address geocoded to US Census tract Standardized Neighborhood Deprivation Index calculated using PCA of census-based: % of family households with children < 18 headed by females, % of age 25 + population with high school degree (reverse coded for those without a high school degree), % of civilian labor force age 16 + unemployed, % of households receiving public	**Construct:** sleep duration **Assessment:** average sleep interval with the most time between 22:00 and 08:00 in minutes, tested using actigraphy for 7 nights **Construct:** sleep quality through Wake After Sleep Onset (WASO) **Assessment:** average sum of minutes in the nighttime sleep interval spent awake after falling asleep but before waking up, tested using actigraphy for 7 nights (greater WASO=lower sleep quality) **Construct:** sleep quality through sleep maintenance efficiency **Assessment:** average nighttime (sleep duration-WASO)/nighttime sleep duration *100%, tested using actigraphy for 7 nights (greater sleep maintenance efficiency=greater sleep quality)	**Mode:** multilevel modeling **Individual level covariates:** age, sex, BMI, race, household income to poverty line ratio, primary caregiver education, family structure, weekend versus weekday, and summer versus school year **Area level covariates:** neighbourhood	No association between more disadvantaged neighborhood and sleep duration (β=− 0.8 minutes sleep duration per unit increase in neighbourhood disadvantage; p>.05) association between more neighbourhood disadvantage and greater WASO (β=4 units WASO per unit increase in neighbourhood disadvantage, p<0.05) Subjects in more disadvantaged neighborhoods had 4.0 more minutes of WASO than those in less disadvantaged neighborhoods (p<0.05) Negative association between more neighbourhood disadvantage and sleep maintenance efficiency (β=-0.8 units sleep maintenance efficiency per unit increase in

	assistance, and % of families below the poverty level Categorized into less disadvantaged and more disadvantaged **Source:** American Community Survey 2015 5-year estimates	disadvantage	neighbourhood disadvantage, p<0.01) Subjects in more disadvantaged neighborhoods had 0.78 percentage points higher sleep maintenance efficiency than those in less disadvantaged neighborhood (p< 0.01)

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Fuller-Rowell et al., 2016[89] USA cross-sectional	n=426 57% female Mean Age=56.8 years SD age=11.4 31.22% Black and 68.78% white	**Construct:** neighborhood disadvantage **Assessment:** subject addresses geocoded to US Census tract index calculated as mean of: % of residents below poverty line, % on public assistance, % with highest level of education less than high school graduation, median household income (reverse-coded), % with highest level of education of a four-year college degree or more (reverse-coded) **Source:** 2000 US Census	**Construct:** sleep quality measured by WASO (sleep quality not explicitly stated in this article) **Assessment:** avg minutes spent awake between sleep onset and rise time, tested using actigraphy for 7 nights (greater WASO=lower sleep quality)	**Model:** multilevel modeling **Individual level covariates:** age, sex, race, cohabitation, household income, education, use of a sleep aid, alcohol consumption, current smoking status, and moderate/vigorous physical activity, BMI, depressive symptoms **Area level covariates:** neighborhood disadvantage, population density	**N**eighbourhood disadvantage associated with greater WASO (β=3.16 units WASO per unit increase in neighbourhood deprivation, p<0.05)

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Perales et al., 2017[90] Australia cross-sectional	n=9,181 48% female Age range=20–70 years	**Construct:** local economic conditions **Assessment:** Australian Bureau of Statistics based **l**ocal unemployment rates Used Statistical Area Level 4 (SA4) of the 2011 Australian Standard Geographical Classification 87 SA4s (local areas) in Australia and 79 of these have at least 50 subjects in current study **Source:** Australian Bureau of Statistics	**Construct:** sleep duration **Assessment:** self-reported total number of sleep minutes in a usual day	multilevel regression **Individual level covariates:** gender, age in year, partnership status, number of children under the age of 5, highest educational qualification, employment status, ethno-migrant background, house tenure, and respondent's general physical health, income poverty **Area level covariates:** local unemployment rate	Local unemployment rates associated with lower sleep duration among individuals who experience material deprivation, lack of prosperity or financial worsening **Statistical results not provided unless requested**

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Fang et al., 2015[91] Boston, Massachusetts, USA cross-sectional	n=3591 54.7% female Mean age=53 years 34.1% Hispanic, 33.1% African American, 32.7% Caucasian	**Construct:** neighborhood socioeconomic status **Assessment:** subject addresses geocoded using ArcGIS to respective neighbourhood level data Neighborhood boundaries defined using Boston Redevelopment Authority Composite z-score calculated using following neighbourhood measures derived from population-weighted averages of 2010 USA census tracts located within the neighbourhood: median value of owner-occupied housing; % of households receiving interest, dividend or net rental income; % of adults 25 years and over with high school degree; % of adults 25 years and over with a college degree; and % of individuals aged 16 years and over in management and professional occupations Categorized into tertiles: low, medium, high SES	**Construct:** sleep duration **Assessment:** self-reported usual sleep in previous month in hours Categorized into quartiles: very short (<5 h), short (5–6.9 h), normative (7–8.9 h) and long (≥9 h)	**Model:** multilevel multinomial models with random intercepts to account for clustering by neighbourhood **Individual level covariates: a**ge, race, marital status, gender, individual SES, alcohol use, physical activity, and smoking status**,** antidepressant use, self-perceived stress, obesity, self-rated health, diabetes, hypertension, cardiovascular disease, sleep medication use	Greater odds of very short sleep in those with low compared to high neighborhood SES (OR=2.12, 95%CI=1.41 to 3.19) Greater odds of very short sleep in those with medium compared to high neighborhood SES (OR=1.82, 95%CI=1.25 to 2.64) Greater odds of short sleep in those with low compared to high neighborhood SES (OR=1.35, 95%CI=1.06 to 1.71) Non statistically significant greater odds of short sleep in those with medium compared to high neighborhood (OR=1.24, 95%CI=1.00 to 1.53) No statistically significant association between odds of long sleep and those with low compared to high neighborhood SES (OR=.99; 95%CI=.62 to 1.59) No statistically significant association between odds of long sleep and those with medium compared to high neighborhood SES (OR=1.22; 95%CI=0.80 to 1.87)

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Dollman et al., 2017[47] South Australia Longitudinal (cross-sectional at 3 time points)?	Year 1985: n=401 47.63% female Year 2004: n=450 50% female Year 2013: n=395 47.85% Age range=10 to 15 years	**Construct:** SES **Assessment:** subject postcodes used to determine Australian Bureau of Statistics-based SEIFA score SEIFA calculated using ABS census-specific at postcode level: economic resources, education, and occupation of householders Dichotomized at survey-specific median to high and low SES	**Construct:** sleep duration **Assessment:** self-reported sleep time and wake up time Excluded sleep duration >14h and <4h	**Model:** Anova for comparisons of sleep duration between survey years, stratified by sex, age (young=10-12.99 years vs. old=13-15.99 years) and SES category and STATA survey command procedure was used to correct for the cluster sampling design and unequal probability of selection	no statistically significant differences in sleep duration between SES categories at any time point (p>0.05) several interaction terms were significant in the original model of sleep duration (P<0.05) Among younger boys low SES, decline in sleep duration from 1985 (576.8±77.9 min) to 2004 (530.0±84.5 min) (p≤0.01) Among older boys low SES, decline in sleep duration from 1985 (535.3±86.1 min) to 2004 (486.0±104.3 min) (p≤0.01) and from 1985 (535.3±86.1 min) to 2013 (496.9±93.5 min) (p≤0.05) No statistically significant changes in sleep duration among high SES (younger or older) boys Among younger girls low SES, decline in sleep duration from 1985 (571.6± 68.9 min) to 2013 (540.7±69.1 min) (p≤0.05) No statistically significant changes in sleep duration among high SES younger girls Among older girls low SES, decline in sleep duration from 1985 (561.9±97.8 min) to 2004 (492.9±89.2 min) (p≤0.001) and from 1985 (561.9±97.8 min) to 2013 (506.9±65.3 min) Among older girls high SES, decline in sleep duration from 1985 (516.2±68.1 min) to 2004 (470.8±72.8 min) (p≤0.001)

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El-Sheikh et al., 2013[92] Rural and semi-rural towns in southeastern USA cross-sectional	n=276 48.19% female Mean age=9.44 years SD age=.71 years 66% European American and 34% African American	**Construct:** community level poverty **Assessment:** based on whether subjects attend Title 1 status school or not Title 1 status=school located in low-income neighborhood	**Construct:** sleep duration **Assessment:** avg total sleep minutes during the sleep period, tested using actigraphy for 7 nights **Construct:** sleep quality, measured by sleep efficiency **Assessment:** avg % of epochs scored as sleep between sleep onset and offset, tested using actigraphy for 7 nights data points that exceeded 4 SDs were removed. Specifically, the following data points were removed: one for sleep minutes,	**Model:** structural equation model, fitted path model regressed on latent construct **Individual level covariates:** single-parent household, child age, medications, and asthma **Area level covariates:** community level poverty	Community poverty associated with lower sleep duration (β=−0.32 minutes sleep per unit increase in community poverty, r=−0.17, p<0.01) Community poverty non statistically significantly associated with lower sleep quality (β=-0.03 units sleep efficiency per unit increase in community poverty, p>0.05)

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Moore et al., 2011[45] USA Cross-sectional	n=247 48.6% female Mean age=13.67 years SD age=.75 years 45.7% non-minority ethnicity, 54.3% ethnic minority	**Construct:** neighbourhood distress **Assessment:** subject's address used to determine corresponding US Census tract Neighborhood distress calculated using tract-specific: (% poverty, % female headed households, % high school dropouts, % males disengaged from workforce Dichotomized to neighborhood stress (any 3 characteristics > 1SD about the mean for all US census tracts) or no neighborhood distress if former not true	**Construct:** sleep duration **Assessment:** sum of the average weekday sleep duration multiplied by 5, and the average weekend sleep duration multiplied by two were divided by 7, tested using actigraphy for 7 nights	**Model:** multiple linear regression **Individual level covariates:** age, gender, pubertal status, minority status, parent income, parental education, school vacation status, ADHD, asthma, birth weight status, BMI **Area level covariates:** neighborhood distress	No statistically significant association between neighbourhood distress and sleep duration

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Olds et al., 2010[93] Australia Cross-sectional cohort study	n=4032 51.07% female Mean age=14 years SD age=2.2 years Community dwelling	**Construct:** SES **Assessment:** subject postcodes used to determine Australian Bureau of Statistics-based SEIFA score SEIFA calculated using ABS census-specific at postcode level: economic resources, education, and occupation of householders Dichotomized to high and low SES	**Construct:** sleep duration **Assessment:** calculated using difference between self-reported bedtime on day 1 and self-reported wake time on day 2	**Model:** factorial ANOVA **Individual covariates:** age, sex, day type **Area level covariates:** SES, geographical location, season	no statistically significant association between SES and sleep duration (p=0.20)
Olds et al., 2006[94] Australia Cross-sectional	n=978 48.32% female Mean age=11.8 years SD age= 0.6 years Community dwelling	**Construct:** SES **Assessment:** subject postcodes used to determine Australian Bureau of Statistics-based SEIFA score SEIFA calculated using ABS census-specific at postcode level: economic resources, education, and occupation of householders	**Construct:** sleep duration **Assessment:** calculated using average of at least 1 weekday and 1 weekend report of sleep minutes	**Model:** linear regression **Individual level covariates:** Physical activity level, minutes spent on various activity subsets, screen time **Area level covariates:** SES	SES associated with greater sleep duration (r-0.07; p=.04) In males, SES associated with greater sleep duration (r=0.13; p=0.01) In females, no statistically significant association between SES and sleep duration (r=0.07; p=.38)

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Williamson et al., 2021[75] USA Cross-sectional	n=14,980 85.1% female Mean age=1.16 years Age range=.5 to 2.99 years Community dwelling	**Construct:** socioeconomic disadvantage **Assessment:** DCI score derived from: % of population without high school diploma or equivalent, % housing vacancy rate, % aged 25-64 without work, % living under poverty line, median income ratio as % of state's median income, % change in # of jobs from previous census period, % change in # of business establishments from previous census period Home addresses linked to DCI scores Categorized into quintiles (highest quintile=most socioeconomic disadvantage) **Source:** US Census Bureau's American Community Survey 5-Year Estimates and Business Patterns Datasets	**Construct:** sleep duration **Assessment:** parent-reported child nighttime and total 24-hour sleep duration using Brief Infant Sleep Questionnaire – Revised (BISQ-R)	**Model:** ANCOVA models with post hoc Bonferroni-adjusted contrasts **Individual level covariates:** age, sex, sharing bed or a room with a caregiver, US region **Area level covariates:** socioeconomic disadvantage	Nighttime sleep duration greater in least distressed (9.44, 95%CI=9.38 to 9.50), second least distressed (9.21, 95%CI=9.14 to 9.27), third least distressed (9.10, 95%CI=9.03 to 9.17) compared to most distressed (8.91 hours, 95%CI=8.83 to 8.98) (p<0.001) Nighttime sleep duration in second most distressed (9.06, 95%CI=8.99 to 9.14) non-statistically significantly greater than those in most distressed (8.91 hours, 95%CI=8.83 to 8.98) Total 24-hours sleep duration greater in least distressed (11.78, 95%CI=11.72 to 11.85), second least distressed (11.61, 95%CI=11.54 to 11.68), third least distressed (11.49, 95%CI=11.41 to 11.56) compared to most distressed (11.29, 95%CI=11.20 to 11.37) (p<0.001) Total 24-hour sleep duration in second most distressed (11.42, 95%CI=11.35 to 11.50) non-statistically significantly greater than those in most distressed (11.29, 95%CI=11.20 to 11.37)

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Sheehan et al., 2018[95] Urban California, USA cross-sectional	n=2,720 48.3% girl Mean age=6.8 years SD age=0 years 49.8% Latino, 26.5% white, 8.6% Black, 7.8% other/multiple, 7.3% Asian,	**Construct:** current neighbourhood poverty **Assessment:** latent trajectory analysis on % of residents who lived in poverty for every Californian census tract Categorized into quartiles (quartile 1=greatest current neighborhood poverty) **Source:** 2005-2009 American Community Survey	**Construct:** sleep duration **Assessment:** mother-reported child sleep/night on weeknights Dichotomized into sleeping recommended amount for age vs. not sleeping recommended amount for age	**Model:** logistic regression **Individual level covariates:** age, gender, race/ethnicity, physical activity, weight, diagnosed with attention deficit disorder, mother's age, number of stressful events experienced by the mother in the past year, the number of stressful events experienced by mother during her childhood, mother's sleep duration, household socioeconomic status, mother's educational attainment, total annual family income, mother's marital status, housing type **Area level covariates:** current neighbourhood poverty	Non-statistically significantly lower odds of not sleeping recommend amount for age in those with second greatest neighbourhood poverty compared to those with greatest neighbourhood poverty (OR=0.92, 95%CI=0.68 to 1.12) Non-statistically significantly lower odds of not sleeping recommend amount for age in those with third greatest neighbourhood poverty compared to those with greatest neighbourhood poverty (OR=0.82, 95%CI=0.59 to 1.18) Non-statistically significantly lower odds of not sleeping recommend amount for age in those with lowest neighbourhood poverty compared to those with greatest neighbourhood poverty (OR=0.80, 95%CI=0.56 to 1.55)

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Watson et al., 2016[96] Washington, USA cross-sectional	n=4,218 62% female Mean age=38.2 years SD age=18 years 91% Caucasian, 9% other	**Construct:** area level deprivation **Assessment:** census tract indicators on %of population aged ≥ 25 y with < 9 y of education, % of population aged ≥ 25 y with at least a high school diploma, % of employed persons aged ≥ 16 y in white-collar occupations, median family income, income disparity (the Log of 100 times the ratio of number of households with < $10,000 income to number of households with ≥ $50,000 income), median home value, median gross rent, median monthly mortgage, % of owner-occupied housing units (home ownership rate)% of civilian labor force population aged > 16 y unemployed (unemployment rate), % of families below poverty level, % of population below 150% of the poverty threshold, % of single-parent households with children aged < 18 y, % of households without a motor vehicle, % of households without a telephone, % of occupied housing units without complete plumbing, % of households with more than one person per room (crowding) **Source:** 2000 census	**Construct:** sleep duration **Assessment:** self-reported # of hours sleep/night	Model: linear regression **Area level covariates:** area-level deprivation	area-level deprivation associated with lower sleep duration (β=−0.080 hours sleep per unit increase in area-level deprivation, p<0.001)

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Clement et al., 2021[34] Mexico cross-sectional	65.8% female Mean age=41.403 years SD age=12.470 years	**Construct:** municipal level income inequality **Assessment:** Gini index **Source:** 2015 EIC survey	**Construct:** sleep quality **Assessment:** self-reported Dichotomized (bad sleep quality vs no bad sleep quality)	**Model:** three-stage least squares **Area level covariates:** municipal level income inequality	In whole sample, association between income inequality and bad quality sleep (0.0405, p<0.01) In women, association between income inequality and bad quality sleep (0.0429, p<0.01) In men, non-statistically significantly association between income inequality and bad quality sleep (0.00576, p>0.05)

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Pabayo et al., 2022[74] United States cross-sectional	n=350,929 50% female 11.0% aged 18–24 years old 35.5% aged 25–44 years old 34.0% aged 45–64 years 19.5% aged 65 and older 64.6% White, 11.6% Black, 15.8% Hispanic, 5.1% Asian, 1.1% Native, 2.0% other Community dwelling	**Construct:** income inequality **Assessment:** Gini index **Source:** US Census	**Construct:** sleep duration **Assessment:** self-reported Categorized into >7 hours, <7 hours (inadequate sleep) and <5 hours (very inadequate sleep)	Model: multilevel logistic regression modeling and baron and Kenny method for mediation **Individual level covariates:** gender, age, race, education, marital status, total household income **Area level covariates:** state-level median income, state-level proportion living in poverty, state-level proportion that is Black, and state-level population size	Slightly greater odds of inadequate sleep (OR = 1.06, 95% CI: 1.00, 1.13) and very inadequate sleep (OR = 1.11, 95% CI: 1.03,1.20) for standard deviation increase in Gini index Significant interaction effect of sex and income inequality wherein the estimated proportion of women obtaining very inadequate sleep was greater than that of men, at higher levels of income inequality Inclusion of poor mental health days as a mediator caused a small attenuation of the effect of income inequality on inadequate sleep (OR = 1.06, 95% CI = 0.99, 1.12) and very inadequate sleep (OR = 1.09, 95% CI = 1.01, 1.17)

3.3.2 Income inequality and sleep

Only two of the included articles explored the association between income inequality and sleep. Clement et al. (2021) found a weak association between Gini index and bad quality sleep (0.0429, $p<0.01$)[97]. Pabayo et al. (2022) found a slightly greater odds of inadequate sleep (OR=1.06, 95% CI=1.00 to 1.13) and very inadequate sleep (OR=1.11, 95% CI=1.03 to 1.20) for a standard deviation increase in the Gini index. They also observed a significant interaction effect of sex and income inequality wherein the estimated proportion of women obtaining very inadequate sleep was greater than that of men, at higher levels of income inequality[98]. The inclusion of poor mental health days as a mediator caused a small attenuation of the effect of income inequality on inadequate sleep (OR=1.06, 95% CI=0.99 to 1.12) and very inadequate sleep (OR=1.09, 95% CI=1.01 to 1.17)[98].

3.3.3 Neighbourhood SES and sleep

The remaining 28 articles assessed neighbourhood SES and sleep. Neighbourhood SES was conceptualized and measured variably across articles. Studies measured neighbourhood SES by geocoding various sets of census tract level indicators (e.g., % with college education, % of households with income below poverty level, % employed, % of households without motor vehicles, % of housing units that are owner occupied, % of households receiving social assistance) to residential locations. Some of these studies conceptualized neighbourhood SES as “neighbourhood socioeconomic status” while others used constructs that when increased indicate lower neighbourhood SES (e.g., neighbourhood social fragmentation, area level deprivation, neighbourhood economic deprivation, neighbourhood socioeconomic disadvantage, neighbourhood disadvantage).

3.3.3.1 Neighbourhood SES and sleep quality

Nine studies measured neighbourhood SES and sleep quality. Sleep quality was defined and assessed in several distinct ways. Some studies asked participants to self-report bad sleep quality vs. good sleep quality, how sleep quality changed from before to during COVID-19, presence or absence of restless sleep, difficulty falling asleep, difficulty staying asleep, waking too early, and feeling well rested upon waking. Other studies measured indicators of sleep quality such as Wake After Sleep Onset (average sum of minutes in the nighttime sleep interval spent awake after falling asleep but before waking up) or sleep efficiency, through actigraphy, a wearable movement-sensitive sleep test.

A. Children

Two studies examined the association between neighbourhood SES and sleep quality in children. Grimes et al. (2019) (n=80) observed that greater neighbourhood deprivation was weakly associated with greater sleep quality[73] while El-Sheikh et al. (2019) (n=276) found a non-statistically significant weak association between community poverty and lower sleep efficiency[92].

B. Teens

One study examined the association between neighbourhood SES and sleep quality in teens. Nahmod et al. (2022) (n=682) found associations between greater neighbourhood disadvantage and greater WASO and between greater neighbourhood disadvantage and lower sleep maintenance efficiency, wherein lower WASO and greater sleep maintenance efficiency was predictive of greater sleep quality[88].

C. Adults

Six studies examined the association between neighbourhood SES and sleep quality in adults with sample sizes ranging from 97[78] to 12,932[72].

Three studies observed an association between greater neighbourhood SES and greater sleep quality: Fuller-Rowell et al. (2016) found an association between neighbourhood disadvantage and greater WASO. Bassett et al. (2014) observed greater odds of restless sleep in women living with neighbourhood disadvantage (OR=1.18, 95%CI=1.01 to 1.38) Raza et al. (2021) found slightly lower non-statistically significant odds of disturbed sleep in the second lowest home neighbourhood SES quartile (OR=0.96, 95% CI=0.78 to 1.20) and highest home neighbourhood SES quartile (OR=0.94, 95% CI=0.68 to 1.30), compared to the lowest home neighbourhood SES quartile[72]. They also found slightly lower non-statistically significant odds of disturbed sleep in the second lowest work neighbourhood SES quartile (OR=0.92, 95% CI=0.75 to 1.12) and second highest work neighbourhood SES quartile (OR=0.97, 95% CI=0.76 to 1.23) compared to the lowest work neighbourhood SES quartile.

Two studies found an association between greater neighbourhood SES and lower sleep quality: Raza et al. (2021) found slightly greater non-statistically significant odds of disturbed sleep in the highest work neighbourhood SES quartile compared to the lowest quartile (OR=1.06, 95% CI=0.78 to 1.40)[72].

Bassett et al reported slightly lower non-statistically significant odds of restless sleep less in men living with neighbourhood disadvantage (OR=0.92, 95%CI=0.72 to 1.17)[86].

Four of these studies observed no association: Hunter et al. (2018) found no statistically significant association between neighbourhood SES and sleep quality but failed to report the direction of association[82]. Similarly Aggarwal et al. (2003) observed no statistically significant differences in sleep disturbance between neighbourhood deprivation quintiles[79] and Rassu et al. (2021) reported no statistically significant differences in changes in sleep quality before-during COVID-19 between 3 neighbourhood deprivation levels[78]. Moreover, Raza et al. (2021) found no difference in odds of disturbed sleep between the second highest and lowest home neighbourhood SES quartile[72].

3.3.3.2 Neighbourhood SES and sleep duration

16 studies measured neighbourhood SES and sleep duration. Some studies used a self- or parent-reported measure of sleep duration while others measured sleep duration through actigraphy.

A. Children

Eight studies examined the association between neighbourhood SES and sleep duration in children with sample sizes ranging from 210[48] to 14,980[75].

Six studies observed an association between greater neighbourhood SES and greater sleep duration: Bagley et al. (2018) found an association between greater neighbourhood economic deprivation and lower sleep duration. Dollman et al. (2017) reported a decline in sleep duration from year 1985 to 2004 among boys and girls with low SES neighbourhoods[47]. Olds et al. observed a correlation between greater neighbourhood SES and greater sleep duration in males[94]. Williamson et al. (2021) observed greater sleep duration in the least distressed, second least distressed, and third least socioeconomically distressed neighbourhood compared to the most distressed[75]. Mackinnon et al. (2020) reported a weak association between greater neighbourhood deprivation and lower sleep duration re[87]. Sheehan et al (n=2,720) found slightly lower non-statistically significantly odds of not sleeping the recommend amount in those with the second greatest (OR=0.92, 95%CI=0.68 to 1.12), second lowest (OR=0.82, 95% CI=0.59 to 1.18) and lowest (OR=0.80, 95% CI=0.56 to 1.55) neighbourhood poverty compared to those with the greatest neighbourhood poverty[95]. Olds et al. observed a non-statistically significant weak correlation between greater neighbourhood SES and greater sleep duration in females[94]. Williamson et al. (2021)

observed greater non-statistically significant nighttime sleep duration in the second most distressed neighbourhoods than those in the most distressed neighbourhoods[75].

Li et al., 2023 observed a non-statistically significant association between greater neighbourhood deprivation and greater sleep duration[76].

Dollman et al. (2017) reported no statistically significant changes in sleep duration over time among child boys or child girls with high neighbourhood SES[47].

B. Teens

Five studies examined the association between neighbourhood SES and sleep duration in teens with sample sizes ranging from 247[45] to 2,493[99].

Dollman et al. (2017) reported a decline in sleep duration over time among teen boys and girls with low neighbourhood SES[47].

Two studies observed an association between greater neighbourhood SES and lower sleep duration: Street et al. (2018) observed an association between neighbourhood poverty and greater sleep duration[80]. Dollman et al. (2017) reported a decline in sleep duration overtime among teen girls with high neighbourhood SES[47].

Four studies reported no association: Troxel et al. (2017) reported no association between neighbourhood poverty and sleep duration[99]. Olds et al. (2010) found no statistically significant association between neighbourhood SES and sleep duration[93]. Likewise, Moore et al. (2011) found no statistically significant association between neighbourhood distress and sleep duration[45]. Dollman et al. (2017) ran ANOVA comparisons of sleep duration across time points and reported no statistically significant changes in sleep duration among teen boys with high neighbourhood SES[47]. Olds et al. (2010), Moore et al. (2011), and Dollman et al. (2017) failed to report the summary measure of association.

C. Adults

Seven studies examined the association between neighbourhood SES and sleep duration in adults with sample sizes ranging from 760[84] to 280,537[85].

Four studies observed an association between greater neighbourhood SES and greater sleep duration: Fang et al. (2015) reported greater odds of very short sleep (<5 hours) in those with low compared to high neighbourhood SES (OR=2.12, 95%CI=1.41 to 3.19), greater odds of very short sleep

in those with medium compared to high neighbourhood SES (OR=1.82, 95%CI=1.25 to 2.64), and greater odds of short sleep (5-6.9 hours) in those with low compared to high neighbourhood SES (OR=1.35, 95%CI=1.06 to 1.71)[91]. They also reported non-statistically significant greater odds of short sleep in those with medium compared to high neighbourhood SES (OR=1.24, 95%CI=1.00 to 1.53)[91]. Perales et al. (2017) reported an association between greater local unemployment rates and lower sleep duration among individuals who experience material deprivation, lack of prosperity or financial worsening[90]. Xiao et al. (2018), observed a greater risk of <5 hours sleep (RRR=1.65, 95% CI=1.45 to 1.89) and 5-6 hours (RRR=1.21, 95%CI=1.15 to 1.27) vs. 7-8 hours of sleep in women in the lowest neighbourhood SES quintile compared to women in the highest neighbourhood SES quintile and a greater risk of <5 hours sleep vs. 7-8 hours sleep in men in the lowest neighbourhood SES quintile compared to men in the highest neighbourhood SES quintile (RRR=1.34, 95% CI=1.16, 1.54)[85]. They also observed a non-statistically significant greater risk of <5 hours vs. 7-8 hours sleep duration in women with >10 decrease in neighbourhood SES (RRR=1.12, 95% CI=1.00 to 1.27)[85]. Xiao et al. (2018) found a slightly greater risk of 5-6 hours sleep vs. 7-8 hours sleep in men in the lowest neighbourhood SES quintile compared to men in the highest neighbourhood SES quintile (RRR=1.07, 95% CI=1.03 to 1.12)[96]. They also found a slightly greater risk of 5-6 hours vs. 7-8 hours nightly sleep duration in men with >10 decrease in neighbourhood SES (RRR=1.07, 95% CI=1.02 to 1.12) [85]. Xiao et al. (2018) observed a non-statistically significant slightly greater risk of 5-6h vs. 7-8 hours sleep duration in women with >10 decrease in neighbourhood SES (RRR=1.04, 95% CI=0.99 to 1.09) and of <5h vs. 7-8 hours sleep duration in men with >10 decrease in neighbourhood SES (RRR=1.09, 95% CI=0.96 to 1.25)[85]. Watson et al. (2016) reported a weak association between area-level deprivation and lower sleep duration.

Three studies observed an association between greater neighbourhood SES and lower sleep duration: Lukic et al. (2021) found non-statistically significantly lower odds of <7 of sleep vs. 7-8 hours of sleep in those with low neighbourhood SES compared to those with high neighbourhood SES (OR=0.38, 95% CI=0.94 to 2.02). Lukic et al. (2021) also observed a statistically significant interaction between neighbourhood street pattern and neighbourhood SES associated with sleep[81]. DeSantis et al. (2013) reported a weak association between greater neighbourhood SES and lower sleep duration. They also found no statistically significant effect modification by sex, race, age, or site[83]. Johnson et al. (2015)

found slightly lower non-statistically significant odds of short sleep duration for a 1 unit increase in neighbourhood disadvantage (OR=0.98, 95%CI=0.83 to 1.16)[84].

3.4 Limitations and gaps

Limitations of the studies on relative income inequality and sleep may include social desirability bias, the tendency to overreport what is perceived as good behavior and underreport what is perceived as poor behavior. For example, participants in Clement et al., (2021) may have underreported low sleep quality and overreported high sleep quality[97] while those in Pabayo et al. (2022) may have underreported low sleep durations and overreported longer sleep durations[74], possibly resulting in an underestimation of association. However, this bias may be mitigated by the anonymity of the Mexican National Health and Nutrition Survey and BRFSS questionnaires used in Clement et al. (2021)[97] and Pabayo et al., (2022)[74], respectively, in which subjects were not asked to disclose their names. Self-reporting bias may also occur in the form of recall bias wherein the likelihood of exposure recall is dependent on outcome status. For instance, in Pabayo et al., (2022), students who have lower sleep duration may recall higher depressive symptoms as a way to understand or justify their slower sleep duration[74].

Findings from both studies may also be subject to selection bias[74,100]. Participants who obtain lower quality of sleep or few hours of sleep tend to have poorer health in general. Such participants may be less likely to have agreed to participate in the surveys, possibly contributing to an underestimation of effect.

Moreover, Clement et al. (2021) dichotomized sleep quality to high vs. low sleep quality[97] and Pabayo et al. (2022) categorized sleep duration to normal, inadequate, and very inadequate sleep[74]. While transforming continuous variables to categorical may have several advantages including simplification of analysis and ease of interpretation of results, this practice may also result in some problems. Firstly, categorizing a continuous variable may cause of information, lowering the power – the capacity to correctly detect a statistically significant result. This may have contributed to the male-specific non-statistically significant association between income inequality and bad quality sleep in observed by Clement et al. (2021)[97].

The cross-sectional nature of both studies prevented the inference of a temporal causal association between income inequality and sleep. This is to say we cannot ascertain that income

inequality comes before lower sleep duration or quality. This study design may also make the results susceptible to reverse causality wherein income inequality may appear to influence sleep duration when in actuality it is sleep duration that influences income inequality. As the impacts of income inequality may take time to come into effect (lagged effects), the cross-sectional study design may have contributed to null findings.

Residual confounding may have been present in Clement et al. (2021) as they failed to control for any covariates. This absence of adjustment for covariates may have contributed to an incorrect direction or under/over estimation of the association between income inequality and sleep quality[97]. Per Pabayo et al. (2022), potential confounders that should have been controlled include gender, age, race, ethnicity, education, marital status, total household income, or area-level income[74]. These variables may be associated with both income inequality and sleep and are not in the causal pathway.

The Baron and Kenny method for mediation used by Pabayo et al. (2022) has several notable limitations[74]. Firstly, with the Baron and Kenny method, mediation can only be identified if a statistically significant direct effect of the exposure on outcome is observed. This is problematic as it is possible for mediation to occur without a statistically significant direct effect[101]. Another limitation is that mediation is only observed if the previously statistically significant association between the exposure and outcome loses its significance when the mediating variable is included in the model. This poses an issue if the change in said direct association from statistically significant to a non-statistically significant mediated association, is trivial, as it would still demonstrate evidence of mediation[101].

Overall, a dearth of literature exists on the association between relative income inequality and sleep. To my knowledge, only two studies have examined the association between relative income inequality and sleep. No prior study has examined the association between relative income inequality and sleep in adolescents or in a Canadian setting.

Chapter 4: Manuscript

4.1 Abstract

Background: Sleep deprivation is a substantial public health concern with 30% of Canadian adolescents not getting the recommended eight to ten hours of sleep. In addition to individual level risk factors for teen sleep deprivation such as increased use of electronic devices and greater sedentary time, according to the Social Determinants of Health Framework, characteristics of the social environment may play a role in sleep. One such characteristic is income inequality, the gap between rich and poor within a society. Existing research has found an association between income inequality and sleep among adults, especially women. However, no prior study has examined the role of income inequality in adolescence. Considering the prevalence of sleep deprivation among teens and income inequality in Canada, describing the association between income inequality and sleep deprivation is of paramount importance.

Objective: The aim of the current study was to examine the association between income inequality and sleep duration among Canadian adolescents, how depression, anxiety and social cohesion mediate this relationship, and how these associations differ by gender.

Methods: Using cross-sectional data of 74,501 secondary school students from wave 7 (year 2018-2019) of the Cohort on Obesity, Marijuana use, Physical activity, Alcohol use, Smoking, and Sedentary behavior (COMPASS) study, multilevel modelling analysis and multilevel path analysis were conducted. Income inequality (Gini index) was measured at the census division level and self-reported sleep duration, gender, depression (measured using the CESD), anxiety (measured using the GAD7), and social cohesion (operationalized as school connectedness) were measured at the individual level.

Results: Greater income inequality (Gini index) was associated with lower sleep duration (β=-3.65 minutes sleep per 1% increase in income inequality, $p<0.001$, 95% CI=-5.63 to -1.68) and increased odds of short sleep (<8 hours) vs. normal sleep (8-10 hours) (OR=1.08, $p<0.001$, 95% CI=1.04 to 1.13). The cross-level interactions between income and gender were significant, suggesting that the income inequality has more adverse effects on the sleep of females than males. A full mediation effect of depression (β=-3.09, p=0.003, 95% CI=-5.15 to -1.03) and anxiety (β=-3.64, p=0.001, 95% CI=-5.88 to -1.41) wherein greater income inequality was associated with higher levels of depression and anxiety, which were in turn, associated with a shorter sleep duration was also found. The mediation effect of

depression was slightly stronger in males than females and the mediation effect of anxiety was stronger in females than males. Moreover, a full mediation effect of social cohesion, wherein greater income inequality was associated with a lower level of social cohesion, which was in turn, associated with a shorter sleep duration, was observed in both the female and male stratified samples (with a stronger effect in the former), but not in the whole sample.

Conclusion: The results provide further reasoning for policy makers to focus on decreasing income inequality to improve the health of society members, such as through progressive taxation policies. Findings suggest that reducing societal income gaps may improve adolescent sleep especially in those attending school in high income inequality areas, females, and those experiencing depression and anxiety. This research also highlights the need for tailored approaches to improving adolescent sleep. Greater investment and research in school-based sleep health promotion should be done in areas with greater income inequality.

4.2 Introduction

Sleep deprivation among Canadian adolescents is a growing public health concern as approximately 30% of Canadian teens do not get the recommended 8-10 hours of sleep[11]. Evidence suggests that certain demographic groups, such as girls and Asian adolescents, and adolescents living in urban areas disproportionately experience sleep deprivation[12]. A longitudinal study of Canadian students in grades 9 to 12 found that the sleep durations of Canadian adolescents decline as they grow older[12], suggesting that this pattern may continue and that sleep deprivation in teen years may persist into adulthood. Given that adolescence is a crucial period for physical, emotional, and social development, in which sleep plays a key role[102], sleep deprivation is linked to an increased risk of adverse health outcomes. Short-term sleep deprivation has been linked to exhaustion and lower cognitive processing speed, attention, and memory[13]. Chronic sleep deprivation intensifies the effects of short term sleep deprivation, increasing the likelihood of anxiety and depression[14,15] and chronic diseases such as cancer, obesity, and hypertension,[16,17]. The impact of sleep deprivation reverberates beyond the individual. Lost working hours attributed to sleep deprivation are estimated to cost the Canadian economy $21.4 billion annually[18]. Given the individual and societal impacts of teen sleep deprivation, understanding, and preventing risk factors for sleep deprivation are of critical importance.

According to the Social Determinants of Health Framework, characteristics of the social environment may play a role in sleep deprivation among teens[32]. Neighbourhood level income[103] and social fragmentation[41] are examples of such characteristics that have been associated with greater and lower teen sleep duration, respectively.

Another albeit relatively understudied characteristic of the social environment is income inequality, the distribution of incomes or gap between rich and poor within a society[33]. Income inequality in Canada has been on the rise since the mid 1990's and has been above the Organization for Economic Co-operation and Development (OECD) country average for over a decade[104]. Income inequality has been associated with poorer health because of mediating factors including decreased social capital, the psychosocial effects of social comparisons, and lower investment in public services such as education and healthcare[33]. However, there exists a dearth of literature on the role of income inequality on sleep, in particular.

One potential mechanism through which income inequality may influence sleep is through the social comparison theory which states individuals base their social and personal worth based on how they compare with others[67]. Increasing income inequality may intensify feelings of worthlessness and insecurity among those members of the community who feel that they have been "left behind"[68]. This may contribute to the association between income inequality and depression[69] and anxiety, common risk factors for sleep deprivation[30]. Another possible mechanism involves social cohesion, the degree of connectedness among groups and people in society. Income inequality has been shown to decrease social cohesion[61], which can in turn increase the risk of mental health conditions such as depression and anxiety[33,71].

To my knowledge, only two studies have examined the role of income inequality on sleep deprivation. Clement et al. (2021), using a sample of adults from the Mexican Health and Nutrition Survey (ENSANUT), found a weak association between greater income inequality and bad quality sleep in women[100]. Pabayo et al. (2022), using cross-sectional data on 350,929 adults aged 18 to 65 from the US 2018 Behavioral Risk Factor Surveillance System (BRFSS), found an association between greater income inequality and greater odds of inadequate (<7 hours) and very inadequate (<5 hours) sleep. They observed a significant interaction effect of gender and income inequality wherein the estimated proportion

of women obtaining very inadequate sleep was greater than that of men, at higher levels of income inequality[74]. They also observed a partial mediation effect of number of poor mental health days wherein the inclusion of poor mental health days as mediator caused a small attenuation of the effect of income inequality on inadequate sleep.

However, no prior study examined the association between income inequality and sleep in adolescents or in a Canadian setting. Several biological and social factors contribute to increased susceptibility to sleep deprivation in adolescence. Adolescence marks the beginning of sleep phase delay, wherein the body's circadian rhythm naturally shifts 1-2 hours forward[19], as well as later melatonin release, leading to delayed sleep onset[12]. Adolescence is also a time of increased independence, lower parental supervision and busier schedules with greater schoolwork and extra-curricular and social commitments, serving as potential barriers to sleep[12]. Developmentally, adolescents are more focused on developing their identity and social acceptance, thus income inequality could be more important given the heightened focus on peer comparisons and importance placed on social status. Moreover, income inequality experienced in childhood has been shown to have a greater adverse impact on health than that experienced in adulthood[36]. Therefore, it is of critical importance to examine the association between income inequality and sleep in this demographic group.

The present study will add to the literature by answering the following research questions: (1) What is the association between income inequality and sleep duration among Canadian adolescents? (2) How do depression, anxiety and social cohesion mediate this relationship? (3) How do these associations differ by gender? Based on prior literature, it is hypothesized that more income inequality is associated with lower sleep duration. It is also hypothesized that this association will be mediated by depression and anxiety wherein in greater income inequality will predict greater depression and anxiety scores, which will in turn predict lower sleep duration. It is proposed that this association will be mediated by social cohesion wherein greater income inequality will be associated with lower social cohesion, which will in turn be associated with lower sleep duration. All associations are hypothesized to be more pronounced in females than males. By elucidating the link and understanding the mechanism of association between income inequality and teen sleep duration, this work may motivate policy makers to implement policies to reduce income inequality and inform school-based interventions to support adequate sleep during this

critical developmental stage. This research may also identify certain subgroups toward whom such efforts should be targeted. Fostering healthy sleep behavior in adolescence will set the course for improved lifetime health and ultimately, reduce the chronic disease burden in Canada.

4.3 Methods

4.3.1 Data source

Data from wave 7 (year 2018-2019; n=74,501) of the COMPASS study was used for this investigation. COMPASS is a prospective longitudinal study (2012-present), with the primary objective of examining the associations between government policies, school environment and youth health behaviors such as diet, substance use, mental health, and physical activity[37]. COMPASS links annual data from teens attending secondary schools across Ontario, Alberta, Quebec, British Columbia, and Nunavut. This study also publishes an annual report containing feedback specific to each participating school[37]. This report promotes knowledge transfer by reporting the school-specific prevalence of health behaviors among students, comparing school specific statistics to provincial and federal statistics and guidelines, and outlining evidence-based recommendations for schoolwide interventions[37].

School-level sampling

Schools were recruited using a convenience sample of school boards that met the following inclusion criteria[37]:

1. Had secondary schools with grades 9 through 12
2. Allowed the use of active-information passive-consent protocol

Student-level sampling

Students were recruited using an in-class whole-school sampling data collection method wherein all grade 9 to 12 students in participating schools were eligible participants. Active-information passive-consent parental permission protocols were implemented. Through either letters or phone calls, parents were informed about the study and were asked to notify the school should they not want their child to participate. Passive consent was used instead of active consent to improve participation rates and prevent biased sample demographics[105]. Parents or students could refuse participation at any time. Detailed COMPASS methods can be found in Leatherdale et al. (2014)[37].

Student questionnaire

Sociodemographic and behavioural data were collected from the 2018-19 student-level questionnaire (Cq). The Cq is a 12 page scantron-based paper questionnaire that asks about health outcomes such as sedentary activity, diet, and mental health, individual behavior such as substance use and bullying, and other factors such as school connectedness and academic outcomes[37]. It is completed by participants once every year, in a classroom setting, and requires 30 to 40 minutes to complete.

The Cqs were administered by classroom teachers who were given detailed instructions for survey administrations to maximize consistency across participating schools[37]. Students who attended school on the date of Cq administration and whose parents did not opt them out of completing survey, were also eligible to participate. Teachers asked students to place their completed Cqs into a blank envelope to safeguard student confidentiality. These were then collected by teachers and put into a larger classroom envelope[37]. The Cqs were eventually collected by the data collector in the school's main office and processed by the COMPASS research team at the University of Waterloo. The participation rate for the 2018-19 Cq was 84.2%. The main reasons for non-participation were absenteeism, classroom spares, and a small number of parental or student refusals (average of 1.2%)[37].

Ethics

The University of Waterloo Research Ethics Board (ORE 30118), the University of Alberta Research Ethics Board (ORE 00040729), Brock University (REB#18-099), CIUSSS de la Capitale Nationale–Université Laval (#MP-13-2017-1264), and the participating school boards approved the COMPASS study protocols and Cqs. Each member of the research team completed the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2) certification[37].

4.3.2 Variables

Exposure

Census division (CD)-level income inequality was measured with the Gini index[53]. Gini index values range from 0, indicating perfect equality (everyone in the CD earns the same income) to 1, indicating perfect inequality (one individual earns all the income in the CD). The Gini index was calculated using the 2016 Canadian Census that was deterministically linked to the COMPASS student questionnaire data using school addresses[77].

Outcome

Sleep duration was measured by asking students how much time per day they usually spent sleeping. Response options ranged from “0 to “9” hours and “0,” “15”, “30”, or “45” minutes[37]. Total sleep duration was calculated in minutes[37]. Sleep duration was also categorized into short (<8 hours) and normal (8-10 hours).

Effect Modifier

Students reported whether they identified as “male” or “female”[37]. Gender has been assessed as a moderator in prior literature exploring the association between income inequality and sleep[74].

Mediators

Depression

Depression was measured by the 10-item Center for Epidemiologic Studies Depression Scale revised (CESD)[106]. Students were asked to indicate how often they felt each of the following ways during the past week: “I was bothered by things that usually don’t bother me”, “I had trouble keeping my mind on what I was doing”, “I felt depressed”, “I felt that everything I did was an effort”, “I felt hopeful about the future”, “ I felt fearful”, “My sleep was restless”, “I was happy”, “ I felt lonely”, and “I could not get going” Response options for each item were 0=“Rarely or none of the time (less than 1 day)”, 1=“Some or a little of the time (1-2 days)”, 2=“Occasionally or a moderate amount of time (3-4 days)”, and 3=“Most of the time (5-7 days)”[106]. The scores of the positive mood items (“I felt hopeful about the future” and “I was happy”) were reversed and the CESD score was calculated by summing the scores across items. The possible range of scores is 0 to 30 and higher CESD scores indicate more depressive symptoms and greater likelihood of depression[106]. The CESD had good internal reliability (α=0.84) in our sample.

Anxiety

Anxiety was measured by the Generalized Anxiety Disorder Assessment (GAD7). Students were asked to indicate how often they felt bothered by the following problems during the past two weeks: “Feeling nervous, anxious, or on edge”, “Not being able to stop or control worrying”, “Worrying too much about different things”, “Trouble relaxing”, “Being so restless that it is hard to sit still”, “Becoming easily annoyed or irritable”, “Feeling afraid as if something awful might happen”. Response options for each item were 0=”Not at all”, 1=”Several days”, 2=”More than half the days”, 3=”Nearly every day”. The anxiety score was calculated by summing the scores for each item. The possible range of scores is 0 to 21 and

greater higher anxiety scores indicate more anxiety symptoms and greater likelihood of anxiety. The GAD7 had excellent internal reliability (α=0.91) in our sample.

Social cohesion

Social cohesion was operationalized as school connectedness[37]. School connectedness was measured with the 5-item version of the National Longitudinal Study of Adolescent Health School Connectedness Scale[107]. Students were asked to indicate how much they agreed to the following: “I feel close to people at my school”, “I am a part of my school”, “I feel safe at my school”, “I feel the teachers at my school treat me fairly”, “I am happy to be at my school”, and “Getting good grades is important to me”. Response options for each item were 1=strongly disagree, 2=disagree, 3=agree, and 4=strongly agree[107]. The school connectedness score was calculated by summing the scores for each item. The possible range of scores is 6 to 24 and greater school connectedness scores indicates greater social cohesion[49]. The National Longitudinal Study of Adolescent Health School Connectedness Scale had good internal reliability (α=0.82) in our sample. Moreover, school connectedness has been used as a proxy for social cohesion in prior literature assessing income inequality in relation to teen health[49].

Individual level covariates

Spending money

Students reported how much money they usually get each week to spend on themselves or to save[37]. Spending money was used as a proxy for individual level income.

Age

Students reported whether they were “12”, “13”, “14”, “15”, “16”, “17”, “18”, or “19 years or older”[37]. Age has been included as a covariate in prior literature assessing the association between income inequality and sleep duration[74].

Race

Students were asked if they identified as White, Black, Asian, Latin, First Nations, Métis, Inuit, or Other. They could select all that applied. Race has been included as a covariate in prior literature assessing the association between income inequality and sleep duration[74].

BMI

BMI was calculated by dividing the students self-reported weight in kilograms by their self-reported height in meters squared[74].

Physical activity time

Physical activity time was calculated by adding the total duration of moderate physical activity with total duration of hard physical activity and dividing by 7. Total duration of moderate physical activity was calculated by summing the student-reported time spent on moderate physical activity for each of the past seven days[74]. Total duration of hard physical activity was calculated by summing the student-reported time spent on hard physical activity for each of the past seven days. Students were provided with examples of moderate ("…lower intensity activities such as walking, biking to school, and recreational swimming") and hard physical activity ("…jogging, team sports, fast dancing, jump-rope, and any other physical activities that increase your heart rate and make you breathe hard and sweat") on the Cq[74].

Area level covariates

All area-level covariates were calculated using the 2016 Canadian Census that was deterministically linked to the COMPASS student questionnaire data using school addresses[77]

CD-level median after tax household income

The CD-level median after tax household income was calculated by calculating the average of household incomes reported in each CD.

Proportion visible minority

The CD-level proportion visible minority was calculated by dividing the number of people living in a CD who identified as a visible minority by the total number of people living in the CD. This variable has been included as a covariate in prior literature assessing the association between income inequality and sleep duration[74].

Geographic status

Geographic status (rural vs. urban) was determined based on students' school address.

Proportion living below the low-income cutoff

The CD-level proportion living below the low-income cutoff was calculated as the percentage of individuals classified as low-income, based on low-income cut-offs, after-tax. The low-income cut-offs differs depending on number of members in household and area.

Population size

The CD-level population size was the total population living in a CD. This variable has been included as a covariate in prior literature assessing the association between income inequality and sleep duration[74].

4.3.3 Statistical analysis

Histograms and skewness and kurtosis values were used to check the normality assumption for each variable. Skewness and kurtosis values of ≤3 and ≤8, respectively, suggested the absence of a overly non-normal distribution. The homoscedasticity assumption was tested using scatterplots. For the sleep duration variable, outliers were defined as less than 3 hours (180 minutes) and were excluded from analysis. For the remaining variables, outliers were defined as more than 3 standard deviations from the mean and excluded from analysis. To improve comparability between the scales of the different variables, I changed the units of: income inequality by multiplying the Gini index by 100 (converted to %), median after-tax neighbourhood household income by dividing by 1000, proportion of visible minority by multiplying by 100 (converted to %), proportion of low income households by multiplying by 100 (converting to %), and population size by dividing by 10,000. Descriptive statistics included frequencies of categorical variables, measures of central tendency and dispersion of continuous variables, and correlations to test the bivariate associations between continuous variables.

The Intraclass Correlation Coefficient (ICC) using an intercept-only model to quantify the variability in sleep duration allocated to CD-level differences was computed.

Individual subjects were clustered within CDs, thus the dependent variable (sleep duration) was measured at the individual-level (level 1) and the independent variable (income inequality) was measured at the CD-level (level 2) using multilevel modeling. Multilevel analysis was conducted using both continuous sleep duration and dichotomous sleep duration (short vs. normal sleep).

To test the between level indirect effects between income inequality and sleep duration through mediation by depression, anxiety, and social cohesion, multilevel path analysis was used. In the multilevel

path models, the dependent variable (sleep duration) and mediating variables (depression score, anxiety score, and social cohesion) were measured at the individual-level (level 1) and the independent variable (income inequality) was measured at the CD-level (level 2). Model fit was assessed using global fit statistics. Close or exact fit is indicated by a $\chi 2$ p-value of <0.05, Root Mean Square Error of Approximation (RMSEA) value between 0.00 and 0.05, Tucker-Lewis Index (TLI) value between 0.95 and 1.00, and comparative fit index (CFI) value between 0.95 and 1.00.

All statistical analyses (descriptive statistics, ICC computation, multilevel analysis, model fit) were performed using R version 4.0.2 (R Project for Statistical Computing) and the Lavaan package[108].

4.4 Results

4.4.1 Descriptive information

74,501 students, from 136 schools and 43 CDs, were included in the analysis. The mean age was around 15 years (SD=1.51) and approximately half the sample was female. Most of the sample was white or living in a rural area. Approximately half the sample experienced short sleep (<8 hours). Average sleep duration was 7.47 (SD=1.39, range=3.00 to 9.75) hours and average Gini index was 36.80% (SD=2.55, range=29.94% to 41.68%). Detailed sample descriptive information can be found in Table 3 and correlations between individual- and CD-level continuous variables are shown in Tables 1A and 2A (Appendix). Given the relatively high correlations involving % low-income households and population size, these variables were excluded from analysis.

All variables met the normality and homoscedasticity assumptions. All variables had <15% missing values or outliers except for BMI (20.22%). Given the relatively high missingness for BMI, it was excluded from the main analyses and instead included in the supplementary analyses shown in Tables 3A to 7A (Appendix).

The ICC value of 0.0887 indicated that 8.87% of the variability in sleep duration was allocated to CD-level differences, warranting a multilevel analysis.

Table 3. Individual- and CD-level descriptive characteristics, COMPASS (2018–2019) (n=74,501)

		Individual-level			
Variables		**n**	**%**	**Missing (%)**	**Outliers (%)**
Gender	Female	36,546	49.6	829 (1.11)	
	Male	37,126	50.4		
Race	White	53,588	77.5	5,342 (7.17)	NA
	Black and persons of colour	15,571	22.5		
Sleep duration	Normal	34,917	49.3	602 (0.81)	3,067 (4.12)
	Short (<8 hours)	35,915	50.7		
Spending money	$0	13,156	19.8	8,131, (10.91%)	NA
	$1 to $5	4,702	7.1		
	$6 to $10	5,344	8.1		
	$11 to $20	9,527	14.4		
	$21 to $40	8,792	13.3		
	$41 to $100	9,466	14.3		
	>$100	15,383	23.2		

Table 3. Individual- and CD-level descriptive characteristics, COMPASS (2018–2019) (n=74,501)

Individual-level							
		Mean (Standard deviation)	**Range**	**Mean (Standard deviation), excluding outliers**	**Range, excluding outliers**	**Missing (%)**	**Outliers (%)**
Sleep duration (in minutes)		422.20 (129.50)	0 to 585.00	448.2 (83.38)	180.00 to 585.00	602 (0.81)	4623 (6.21)
Age (in years)		15.16 (1.51)	12 to 19	-	-	541 (0.73)	0
Depression score		8.77 (6.04)	0.00 to 30.00	8.62 (5.81)	0 to 26.00	10,854 (14.57) After filling from other years: (6499 (8.72))	533 (0.72%)
Anxiety score		6.15 (5.59)	0.00 to 21.00	-	-	6,216 (8.34)	0
Social cohesion score		18.50 (3.36)	6.00 to 24.00	18.61 (3.17)	9.00 to 24.00	3,088 (4.14)	687 (0.92)
BMI		21.73 (4.35)	10.01 to 49.99	21.42 (3.66)	10.01 to 34.78	20,749 (27.85) After filling from other years: (15063 (20.22))	1042 (1.40)
Physical activity time		108.21 (82.63)	0 to 570.00	103.1 (71.95)	0 to 355.71	1,777 (2.39)	1,123 (1.51)
CD-level							
Income inequality		36.84 (2.61)	29.94 to 46.16	36.80 (2.55)	29.94 to 41.68	0	326 (0.44)
Median after-tax neighbourhood household income (in $1000 units)		59.45 (8.77)	44.29 to 87.18	59.24 (8.46)	44.29 to 82.80	0	555 (0.74)
% visible minority		12.22 (14.25)	0.59 to 49.16	-	-	0	0
% low income households		7.58 (3.23)	1.76 to 13.94	-	-	0	0
Population size (in 10,000 units)		55.25(67.42)	1.30 to 246.34	-	-	0	0
		n	**%**				
Geographic status	Urban	602 (0.81)	4623 (6.21)			0	NA
	Rural	602 (0.81)	4623 (6.21)				

4.4.2 Multilevel modelling analysis

4.4.2.1 Multilevel model with continuous sleep duration outcome

Table 4 displays the crude and adjusted associations with sleep duration as the outcome. Per the adjusted analysis, a $1000 increase in CD-level median household income was associated with a 0.35 minute decrease in sleep duration (p=0.15, 95%CI=-0.84 to 0.14). Males obtained 8.89 more minutes of sleep than females (p<0.001, 95% CI=7.61 to 10.17). Sleep duration was on average 9.37 minutes greater in white adolescents than those who were Black or a person of colour (p<0.001, 95% CI=7.57 to 11.16). Furthermore, a 1 year increase in age was associated with 9.78 minutes shorter sleep duration (p<0.001, 95% CI=-10.29 to -9.27).

In the crude analysis, a 1% increase in Gini index (income inequality) was associated with a 5.92 minute decrease in sleep duration (p<0.001, 95% CI=-8.40 to -3.44). This association remained statistically significant but decreased slightly after adjusting for confounders (β=-3.65, p<0.001, 95% CI=-5.63 to -1.68). Moreover, a statistically significantly interaction effect between gender and income inequality was observed (β=1.83, p<0.001, 95% CI=1.33 to 2.33). Stratified analyses can be found in Table 5. The adjusted association between income inequality and shorter sleep duration appeared more pronounced in females (β=-4.40, p<0.001, 95% CI=-6.83 to -1.97) than males (β=-2.80, p=0.002, 95% CI=-4.46 to -1.15). The equations for crude, adjusted and adjusted + interaction models can be found below.

Where $Sleep\_duration_{ij}$ is the sleep duration for student I (i=1,…..74,501) in census division j (j=1,….43). π_{0j} is the mean score across all census divisions. u_j is the effect of census division j, and e_{ij} is the student level residual error term. The census division effects and the student level residual errors are assumed independent and normally distributed with zero means and constant variances:

<u>Crude</u>

Level 1:
$Sleep\_duration_{ij} = \pi_{0j} + e_{ij}$

Level 2:
$\pi_{0j} = y_{00} + y_{01}gini\_index + u_{0j}$

Composite model:
$Sleep\_ duration_{ij} = y_{00} + y_{01}gini\_index + u_{0j} + e_{ij}$

Where:
π_{0j}=660.59
y_{01}=-5.92

Adjusted

Level 1:
$Sleep\_duration_{ij} = \pi_{0j} + \pi_{1j}gender_{ij} + \pi_{2j}race_{ij} + \pi_{3j}spending\_1to5_{ij} + \pi_{4j}spending\_6to10_{ij} + \pi_{5j}spending\_11to20_{ij} + \pi_{6j}spending\_21to40_{ij} + \pi_{7j}spending\_41to100_{ij} + \pi_{8j}spending\_100_{ij} + \pi_{9j}age_{ij} + e_{ij}$

Level 2:
$\pi_{0j} = y_{00} + y_{01}gini\_index + y_{02}median\_income + y_{03}visible\_minority + y_{04}geographic\_area + u_{0j}$

$\pi_{1j} = y_{10}$
$\pi_{2j} = y_{11}$
$\pi_{3j} = y_{12}$
$\pi_{4j} = y_{13}$
$\pi_{5j} = y_{14}$
$\pi_{6j} = y_{15}$
$\pi_{7j} = y_{16}$
$\pi_{8j} = y_{17}$
$\pi_{9j} = y_{18}$

Composite model:
$Sleep\_duration_{ij} = y_{00} + y_{10}gender_{ij} + y_{11}race_{ij} + y_{12}spending\_1to5_{ij} + y_{13}spending\_6to10_{ij} + y_{14}spending\_11to20_{ij} + y_{15}spending\_21to40_{ij} + y_{16}spending\_41to100_{ij} + y_{17}spending\_100_{ij} + y_{18}age_{ij} + y_{01}gini\_index + y_{02}median\_income + y_{03}visible\_minority + y_{04}geographic\_area + u_{0j} + e_{ij}$

Where:
$\pi_{0j} = 737.30$
$y_{10} = 8.89$
$y_{11} = 9.37$
$y_{12} = -1.06$
$y_{13} = -0.71$
$y_{14} = 1.03$
$y_{15} = -0.004$
$y_{16} = -2.69$
$y_{17} = 0.39$
$y_{18} = -9.78$
$y_{01} = -3.65$
$y_{02} = -0.35$
$y_{03} = -0.34$
$y_{04} = 29.95$

Adjusted + interaction

Level 1:
$Sleep\_duration_{ij} = \pi_{0j} + \pi_{1j}gender_{ij} + \pi_{2j}race_{ij} + \pi_{3j}spending\_1to5_{ij} + \pi_{4j}spending\_6to10_{ij} + \pi_{5j}spending\_11to20_{ij} + \pi_{6j}spending\_21to40_{ij} + \pi_{7j}spending\_41to100_{ij} + \pi_{8j}spending\_100_{ij} + \pi_{9j}age_{ij} + e_{ij}$

Level 2:
$\pi_{0j} = y_{00} + y_{01}gini\_index + y_{02}median\_income + y_{03}visible\_minority + y_{04}geographic\_area + y_{05}gini\_indexXgender + u_{0j}$

$\pi_{1j} = y_{10}$
$\pi_{2j} = y_{11}$
$\pi_{3j} = y_{12}$
$\pi_{4j} = y_{13}$
$\pi_{5j} = y_{14}$
$\pi_{6j} = y_{15}$

$\pi_{7j} = \gamma_{16}$
$\pi_{8j} = \gamma_{17}$
$\pi_{9j} = \gamma_{18}$

Composite model:
$Sleep\_duration_{ij} = \gamma_{00} + \gamma_{10}gender_{ij} + \gamma_{11}race_{ij} + \gamma_{12}spending\_1to5_{ij} + \gamma_{13}spending\_6to10_{ij} + \gamma_{14}spending\_11to20_{ij} + \gamma_{15}spending\_21to40_{ij} + \gamma_{16}spending\_41to100_{ij} + \gamma_{17}spending\_100_{ij} + \gamma_{18}age_{ij} + \gamma_{01}gini\_index + \gamma_{02}median\_income + \gamma_{03}visible\_minority + \gamma_{04}geographic\_area + \gamma_{05}gini\_indexXgender + u_{0j} + e_{ij}$

Where:
$\pi_{0j} = 770.20$
$\gamma_{10} = -58.49$
$\gamma_{11} = 9.30$
$\gamma_{12} = -1.08$
$\gamma_{13} = -0.68$
$\gamma_{14} = 1.01$
$\gamma_{15} = -0.02$
$\gamma_{16} = -2.89$
$\gamma_{17} = -0.45$
$\gamma_{18} = -9.78$
$\gamma_{01} = -4.54$
$\gamma_{02} = -0.36$
$\gamma_{03} = -0.34$
$\gamma_{04} = 2.98$
$\gamma_{05} = 1.83$

Table 4. Cross-sectional multilevel associations between income inequality and sleep duration (continuous) in Canadian secondary school students (n=57,021)

Variables	Sleep duration (minutes)								
	Crude			Adjusted			Adjusted + interaction		
	β	P-value	95% CI	β	P-value	95% CI	β	P-value	95% CI
Intercept	660.59	<0.001	571.32 to 749.99	737.30	<0.001	661.90 to 812.54	770.20	<0.001	694.39 to 845.77
CD-level									
Gini index	-5.92	<0.001	-8.40 to -3.45	-3.65	<0.001	-5.63 to -1.68	-4.54	<0.001	-6.52 to -2.55
Median after-tax neighbourhood household income (in $1000 units)				-0.35	0.15	-0.84 to 0.14	-0.36	0.15	-0.84 to 0.13
% visible minority				-0.34	0.26	-0.95 to 0.26	-0.34	0.26	-0.95 to 0.26
Geographic status (ref=rural)									
Urban				29.95	0.01	9.02 to 50.88	2.98	0.01	8.96 to 50.73
Individual-level									
Gender (ref=female)									
Male				8.89	<0.001	7.61 to 10.17	-58.49	<0.001	-76.86 to -40.11
Gini interaction							1.83	<0.001	1.33 to 2.33
Race (ref=Black and persons of colour)									
White				9.37	<0.001	7.57 to 11.16	9.30	<0.001	7.51 to 11.10
Spending money (ref=$0)									
$1 to $5				-1.06	0.24	-2.83 to 0.70	-1.08	0.23	-2.85 to 0.68
$6 to $10				-0.71	0.39	-2.34 to 0.91	-0.68	0.41	-2.30 to 0.95
$11 to $20				1.03	0.28	-0.82 to 2.88	1.01	0.29	-0.84 to 2.86
$21 to $40				-0.004	0.28	-1.91 to 1.91	-0.02	0.99	-1.92 to 1.89
$41 to $100				-2.69	0.01	-4.90. to -0.86	-2.89	0.01	-4.90 to -0.86
>$100				0.39	0.69	-2.26 to 1.49	-0.45	0.64	-2.33 to 1.43
Age				-9.78	<0.001	-10.29 to -9.27	-9.78	<0.001	-10.29 to -9.28

Table 5. Cross-sectional multilevel associations between income inequality and sleep duration (continuous) in Canadian secondary school students, stratified by gender

Variables	Sleep duration (minutes)											
	Females (n=28,646)						Males (n=28,375)					
	Crude			Adjusted			Crude			Adjusted		
	β	P-value	95% CI	β	P-value	95% CI	β	P-value	95% CI	β	P-value	95% CI
Intercept	681.99	<0.001	584.43 to 779.71	739.53	<0.001	646.51 to 832.33	640.61	<0.001	556.25 to 725.38	743.90	<0.001	680.08 to 807.45
CD-level												
Gini index	-6.60	<0.001	-9.31 to -3.89	-4.40	<0.001	-6.83 to -1.97	-5.29	<0.001	-7.64 to -2.95	-2.80	0.002	-4.46 to -1.15
Median after-tax neighbourhood household income (in $1000 units)				-0.43	0.16	-1.03 to 0.17				-0.31	0.14	-0.72 to 0.11
% visible minority				-0.43	0.25	-1.17 to 0.32				-0.26	0.31	-0.76 to 0.25
Geographic status (ref=rural)												
Urban				31.39	0.02	5.73 to 57.00				27.77	0.002	10.82 to 44.84
Individual-level												
Race (ref=Black and persons of colour)												
White				10.98	<0.001	8.42 to 13.55				7.72	<0.001	5.21 to 10.22
Spending money (ref=$0)												
$1 to $5				0.39	0.76	-2.12 to 2.91				-2.72	0.03	-5.20 to -0.24
$6 to $10				0.36	0.76	-1.94 to 2.67				-1.73	0.14	-4.2 to 0.55
$11 to $20				0.40	0.76	-2.18 to 2.98				2.029	0.13	-0.63 to 4.69
$21 to $40				0.30	0.82	-2.34 to 2.94				0.01	1.00	-2.76 to 2.77
$41 to $100				-2.99	0.04	-5.78 to -0.21				-2.71	0.07	-5.64 to 0.22
>$100				-0.74	0.58	-3.33 to 1.85				-0.19	0.89	-2.91 to 2.54
Age				-7.82	<0.001	-8.54 to -7.10				-11.86	<0.001	-12.57 to -11.15

4.4.2.2 Multilevel model with dichotomous sleep duration outcome

Table 6 displays the crude and adjusted associations with dichotomous sleep duration (normal vs short) as the outcome. Per the adjusted analysis, males were 20% less likely than females to experience short sleep duration (OR=0.80, 95% CI=0.77 to 0.83). Moreover, white teens were 21% less likely to obtain short sleep than teens who were Black or a person of colour (OR=0.79, p<0.001, 95% CI=0.76 to 0.83). Teens who lived in urban areas had 44% decreased odds of short sleep than those who lived in rural areas (OR=0.56, p=0.01, 95% CI=0.36 to 0.87). A 1 year increase in age was associated with 28% increased odds of short sleep (OR=1.28, p<0.001, 95% CI=1.26 to 1.29).

In the crude analysis, a 1% increase in income inequality was associated with 15% increased odds of short sleep duration (OR=1.15, p<0.001, 95% CI=1.09 to 1.21). This effect was attenuated but nevertheless remained statistically significant in the adjusted analysis (OR=1.08, p<0.001, 95% CI=1.04 to 1.13). Moreover, a statistically significantly interaction effect between gender and income inequality was observed (OR=0.95, p<0.001, 95% CI=0.94 to 0.96). Stratified analyses can be found in Table 7. Whole sample and gender stratified crude associations are illustrated in Figure 2. The adjusted association between income inequality and increased odds of short vs. normal sleep appeared stronger in females (OR=1.10, p<0.001, 95% CI=1.04 to 1.17) than males (OR=1.06, p<0.01, 95% CI=1.02 to 1.10).

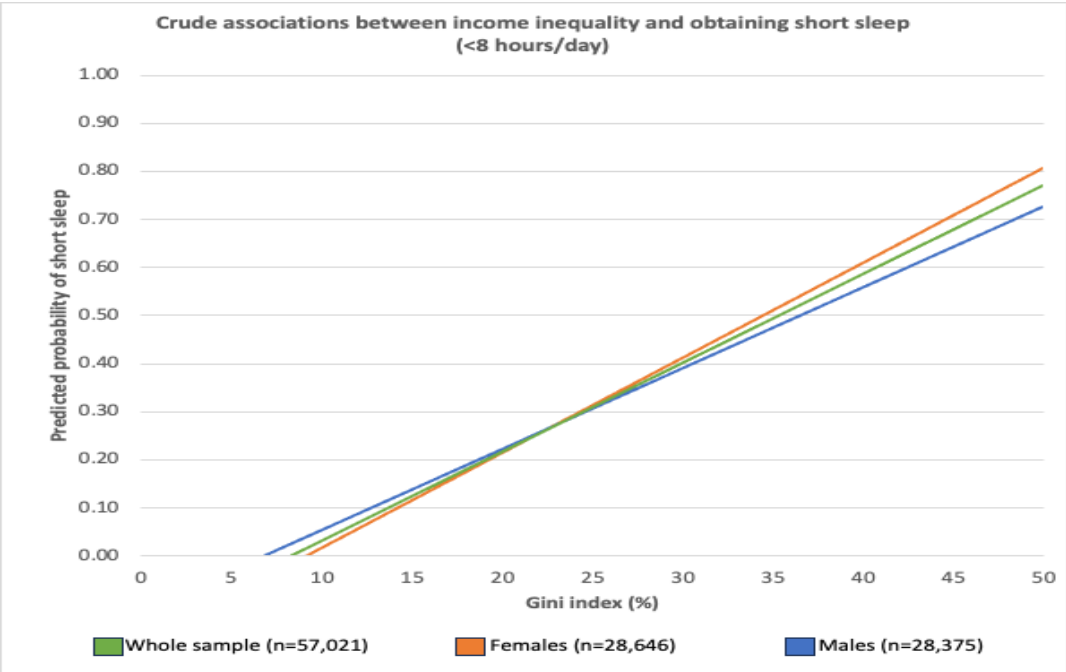

Figure 2. Crude associations between income inequality and obtaining short sleep

Table 6. Cross-sectional multilevel associations between income inequality and odds for obtaining short sleep (<8 hours) in Canadian secondary school students (n=57,021)

Variables	<8 hours sleep duration (ref: 8-10 hours sleep)								
	Crude			Adjusted			Adjusted + interaction		
	OR	P-value	95% CI	OR	P-value	95% CI	OR	P-value	95% CI
Intercept	0.01	<0.001	0.00 to 0.05	0.001	<0.001	0.00 to 0.01	0.001	<0.001	0.0001 to 0.002
CD-level									
Gini index	1.15	<0.001	1.09 to 1.21	1.08	<0.001	1.04 to 1.13	1.11	<0.001	1.06 to 1.16
Median after-tax neighbourhood household income (in $1000 units)				1.01	0.20	1.00 to 1.02	1.01	0.19	1.00 to 1.02
% visible minority				1.01	0.15	1.00 to 1.02	1.01	0.15	1.00 to 1.02
Geographic status (ref=rural)									
Urban				0.56	0.01	0.36 to 0.87	0.56	0.01	0.36 to 0.87
Individual-level									
Gender (ref= female)									
Male				0.80	<0.001	0.77 to 0.83	5.20	<0.001	3.13 to 8.62
Gini interaction							0.95	<0.001	0.94 to 0.96
Race (ref= Black and persons of colour)									
White				0.79	<0.001	0.76 to 0.83	0.80	<0.001	0.76 to 0.84
Spending money (ref= $0)									
$1 to $5				1.04	0.08	1.00 to 1.10	1.04	0.07	1.00 to 1.10
$6 to $10				1.00	0.98	0.96 to 1.04	1.00	0.96	0.96 to 1.04
$11 to $20				0.99	0.78	0.94 to 1.04	0.99	0.79	0.94 to 1.04
$21 to $40				0.98	0.53	0.93 to 1.04	0.98	0.53	0.93 to 1.04
$41 to $100				1.03	0.27	0.98 to 1.09	1.03	0.27	0.98 to 1.09
>$100				1.02	0.45	0.97 to 1.07	1.02	0.40	0.97 to 1.08
Age				1.28	<0.001	1.26 to 1.29	1.28	<0.001	1.25 to1.28

Table 7. Cross-sectional multilevel associations between income inequality and odds for obtaining short sleep (<8 hours), in Canadian secondary school students, stratified by gender

Variables	Sleep duration											
	Females (28,646)						Males (28,375)					
	Crude			Adjusted			Crude			Adjusted		
	OR	P-value	95% CI	OR	P-value	95% CI	OR	P-value	95% CI	OR	P-value	95% CI
Intercept	0.004	<0.001	0.0005 to 0.04	0.001	<0.001	0.0001 to 0.01	0.01	<0.001	0.002 to 0.06	0.001	<0.001	0.0003 to 0.004
CD-level												
Gini index	1.16	<0.001	1.09 to 1.24	1.10	<0.001	1.04 to 1.17	1.13	<0.001	1.08 to 1.19	1.06	<0.001	1.02 to 1.10
Median after-tax neighbourhood household income (in $1000 units)				1.01	0.20	1.00 to 1.02				1.01	0.22	1.00 to 1.01
% visible minority				1.01	0.20	0.99 to 1.03				1.01	0.13	1.00 to 1.02
Geographic status (ref=rural)												
Urban				0.53	0.04	0.29 to 0.96				0.59	0.002	0.42 to 0.82
Individual-level												
Race (ref=Black and persons of colour)												
White				0.76	<0.001	0.71 to 0.82				0.82	<0.001	0.77 to 0.88
Spending money (ref=$0)												
$1 to $5				1.00	0.89	0.94 to 1.08				1.09	0.01	1.02 to 1.16
$6 to $10				0.99	0.65	0.92 to 1.05				1.01	0.70	0.95 to 1.08
$11 to $20				1.00	0.90	0.93 to 1.07				0.98	0.61	0.91 to 1.06
$21 to $40				0.94	0.11	0.88 to 1.01				1.02	0.58	0.95 to 1.10
$41 to $100				1.05	0.23	0.97 to 1.13				1.02	0.70	0.94 to 1.09
>$100				1.03	0.42	0.96 to 1.11				1.01	0.70	0.94 to 1.09
Age				1.22	<0.001	1.19 to 1.24				1.34	<0.001	1.32 to 1.37

4.4.3 Multilevel path analysis

4.4.3.1 Multilevel path analysis with depression as a mediator

4.4.3.1.1 Whole sample

The following global fit measures were obtained for the path model (Figure 3): $\chi2(9)= 91.186$, $p<0.001$, TLI=0.999 (close fit), CFI=1.00 (exact fit), RMSEA=0.01 (close fit).

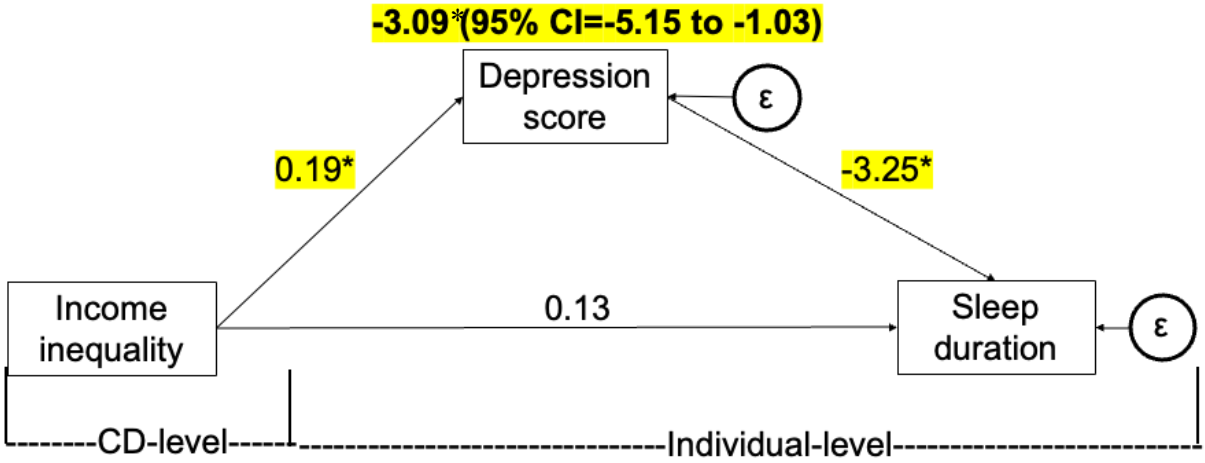

Figure 3. Path model with depression as a mediator
*p<0.05

The multilevel mediation analysis revealed no significant direct effect of income inequality on sleep duration after adjusting for gender, age, and race at the individual-level and % visible minority, median after-tax neighbourhood household income, and geographic status at the CD-level (β=0.13, p=0.88, 95% CI=-1.53 to 1.79).

The mediated path revealed that a 1% increase in income inequality was associated with a 0.19 unit increase in depression score (p<0.001, 95% CI=0.10 to 0.28). Moreover, a 1 unit increase in depression score was associated with a 3.25 minute decrease in sleep duration (p<0.001, 95% CI=-3.36 to -3.14). A significant overall indirect effect of income inequality on sleep duration through mediation by depression score was observed (β=-3.09, p=0.003, 95% CI=-5.15 to -1.03).

The multilevel path analysis findings are detailed in Table 8. The equations for the multilevel path analysis can be found below.

Level 1:

$E(sleep\_duration) = \beta_1 cesd + \beta_2 gender + \beta_3 race + \beta_4 age$

Level 2:

$E(sleep\_duration) = a*\beta_5 cesd + c*\beta_6 gini\_index + \beta_7 gender + \beta_8 race + \beta_9 age + \beta_{10} median\_income + \beta_{11} visible\_minority + \beta_{12} geographic\_status$

$E(cesd) = d*\beta_{13} gini\_index$

$E(gini\_index) = e*\beta_{14} median\_income + f*\beta_{15} visible\_minority + g*\beta_{16} geographic\_status$

Indirect and total effects:

ad = a*d
ce = c*e
cf = c*f
cg = c*g

Total=ad + ce + cf + cg

Where:
$\beta_1 = -3.25$
$\beta_2 = -0.04$
$\beta_3 = 8.76$
$\beta_4 = -8.97$
$\beta_5 = -16.28$
$\beta_6 = 0.13$
$\beta_7 = -0.06$
$\beta_8 = 1.04$
$\beta_9 = -14.95$
$\beta_{10} = 0.25$
$\beta_{11} = -0.27$
$\beta_{12} = 2.90$
$\beta_{13} = 0.19$
$\beta_{14} = -0.01$
$\beta_{15} = 0.14$
$\beta_{16} = -1.12$

Table 8. Multilevel path analysis findings with depression as mediator, COMPASS (2018-2019) (n=58,232)

Outcome	Predictor	*β*	P-value	95% CI
Sleep duration	Income inequality	0.13	0.88	-1.53 to 1.79
	Depression score	-3.25	<0.001	-3.36 to -3.14
	Gender (ref=female)	-0.04	0.95	-1.28 to 1.20
	Race (ref=Black and persons of colour)	8.76	<0.001	7.03 to 10.49
	Age	-8.97	<0.001	-9.42 to -8.53
Depression score	Income inequality	0.19	<0.001	0.10 to 0.28
Income inequality	% visible minority	0.14	0.001	0.06 to 0.23
	Median after-tax neighbourhood household income	-0.01	0.83	-0.08 to 0.07
	Geographic status (ref=rural)	-1.12	0.51	-4.43 to 2.20

4.4.3.1.2 Gender-stratified

The mediation effect of depression score on the association between income inequality and sleep duration appeared slightly stronger in males (β=-3.25, p=0.002, 95% CI=-5.29 to -1.21) than females (β=-2.97, p=0.01, 95% CI=-5.25 to -0.70).

4.4.3.1.2.1 Females

The following global fit measures were obtained for the path model (Figure 4): $\chi 2(7)=61.50$, $p<0.001$, TLI=0.998 (close fit), CFI=0.999 (close fit), RMSEA=0.016 (close fit).

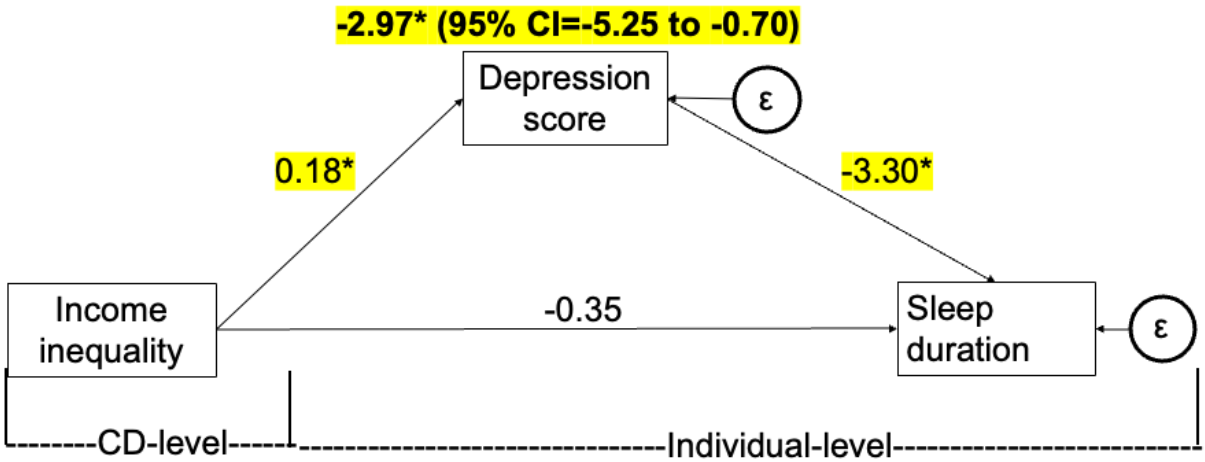

Figure 4. Path model with depression as a mediator, female only sample
*p<0.05

The multilevel mediation analysis revealed no significant direct effect of income inequality on sleep duration after adjusting for age and race at the individual- level and % visible minority, median after-tax neighbourhood household income, and geographic status at the CD- level (β=-0.35, p=0.76, 95% CI=-2.58 to 1.88).

The mediated path revealed that a 1% increase in income inequality predicted a 0.18 unit increase in depression score (p=0.001, 95% CI=0.08 to 0.29). Moreover, a 1 unit increase in depression score predicted a 3.30 minute decrease in sleep duration (p<0.001, 95% CI=-3.44 to -3.16). A significant overall indirect effect of income inequality on sleep duration through mediation by depression score was observed (β=-2.97, p=0.01, 95% CI=-5.25 to -0.70).

The multilevel path analysis findings are detailed in Table 9.

Table 9. Multilevel path analysis findings with depression as mediator, COMPASS 2018-2019, female only sample (n=29,653)

Outcome	Predictor	*β*	P-value	95% CI
Sleep duration	Income inequality	-0.35	0.76	-2.58 to 1.88
	Depression score	-3.30	<0.001	-3.44 to -3.16
	Race (ref=Black and persons of colour)	11.64	<0.001	9.22 to 14.07
	Age	-7.07	<0.001	-7.69 to -6.45
Depression score	Income inequality	0.18	0.001	0.08 to 0.29
Income inequality	% visible minority	0.14	0.002	0.05 to 0.22
	Median after-tax neighbourhood household income	-0.01	0.85	-0.08 to 0.07
	Geographic status (ref=rural)	-0.98	0.56	-4.29 to 2.34

4.4.3.1.2.2 Males

The following global fit measures were obtained for the path model (Figure 5): $\chi2(7)=69.32$, $p<0.001$, TLI=0.998 (close fit), CFI=0.999 (close fit), RMSEA=0.018 (close fit).

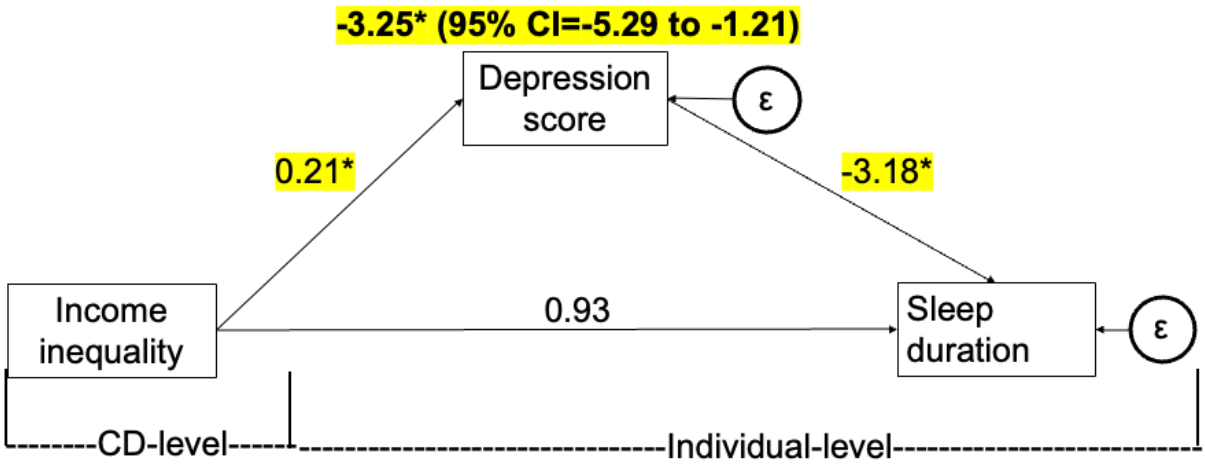

Figure 5. Path model with depression as a mediator, male only sample
*p<0.001

The multilevel mediation analysis revealed no significant direct effect of income inequality on sleep duration after adjusting for age and race at the individual- level and % visible minority, median after-tax neighbourhood household income, and geographic status at the CD- level (β=0.93, p=0.24, 95% CI=-0.63 to 2.49).

The mediated path revealed that a 1% increase in income inequality predicted a 0.21 unit increase in depression score (p<0.001, 95% CI=0.13 to 0.29). Moreover, a 1 unit increase in depression score predicted a 3.18 minute decrease in sleep duration (p<0.001, 95% CI=-3.36 to -3.01). A significant overall indirect effect of income inequality on sleep duration through mediation by depression score was observed (β=-3.25, p=0.002, 95% CI=-5.29 to -1.21).

The multilevel path analysis findings are detailed in Table 10.

Table 10. Multilevel path analysis findings with depression as mediator, COMPASS (2018-2019), male only sample (n=28,579)

Outcome	Predictor	β	P-value	95% CI
Sleep duration	Income inequality	0.93	0.24	-0.63 to 2.49
	Depression score	-3.18	<0.001	-3.36 to -3.01
	Race (ref=Black and persons of colour)	5.78	<0.001	3.32 to 8.24
	Age	-10.95	<0.001	-11.59 to -10.31
Depression score	Income inequality	0.21	<0.001	0.13 to 0.29
Income inequality	% visible minority	0.14	<0.001	0.06 to 0.23
	Median after-tax neighbourhood household income	-0.01	0.82	-0.09 to 0.07
	Geographic status (ref=rural)	-1.17	0.49	-4.49 to 2.15

4.4.3.2 Multilevel path analysis with anxiety as a mediator

4.4.3.2.1 Whole sample

The following global fit measures were obtained for the path model (Figure 6): $\chi^2(9)=101.00$, p<0.001, TLI=0.999 (close fit), CFI=1.00 (exact fit), and RMSEA=0.01 (close fit).

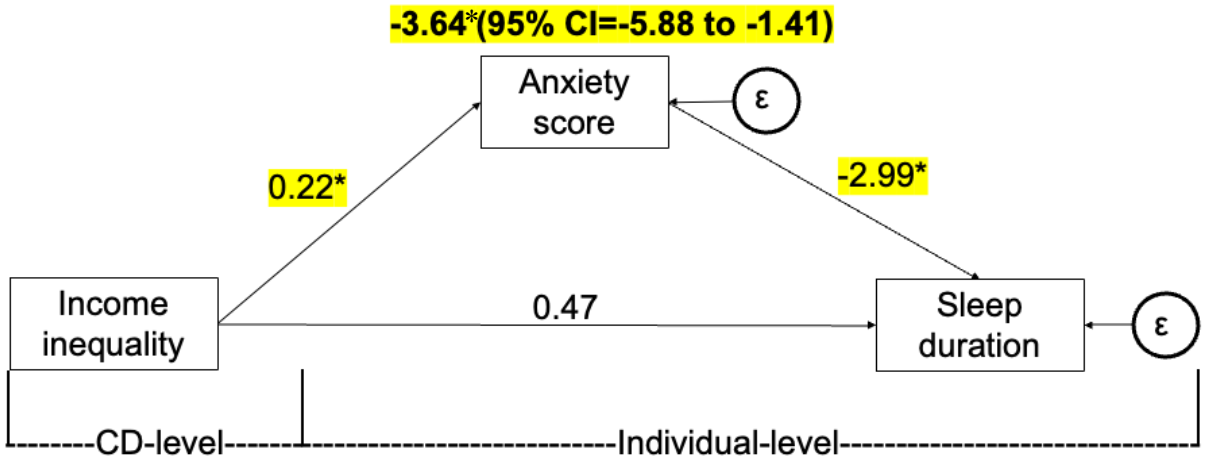

Figure 6. Path model with anxiety as a mediator
*p<0.05

The multilevel mediation analysis revealed no significant direct effect of income inequality on sleep duration after adjusting for gender, age, and race at the individual-level and % visible minority, median after-tax neighbourhood household income, and geographic status at the CD-level (β=0.26, p=0.73, 95% CI=-1.19 to 1.71).

The mediated path revealed that a 1% increase in income inequality was associated with a 0.22 unit increase in anxiety score (p<0.001, 95% CI=0.11 to 0.34). Moreover, a 1 unit increase in anxiety score was associated with a 2.99 minute decrease in sleep duration (p<0.001, 95% CI=-3.11 to -2.87). A significant overall indirect effect of income inequality on sleep duration through mediation by anxiety score was observed (β=-3.64, p=0.001, 95% CI=-5.88 to -1.41).

The multilevel path analysis findings are detailed in Table 11. The equations for the multilevel path analysis can be found below.

Level 1:

$E(sleep\_duration) = \beta_1 gad + \beta_2 gender + \beta_3 race + \beta_4 age$

Level 2:

$E(sleep\_duration) = a*\beta_5 gad + c*\beta_6 gini\_index + \beta_7 gender + \beta_8 race + \beta_9 age + \beta_{10} median\_income + \beta_{11} visible\_minority + \beta_{12} geographic\_status$

$E(gad) = d*\beta_{13} gini\_index$

$E(gini\_index) = e*\beta_{14} median\_income + f*\beta_{15} visible\_minority + g*\beta_{16} geographic\_status$

Indirect and total effects:

ad = a*d
ce = c*e
cf = c*f
cg = c*g

Total=ad + ce + cf + cg

Where:

β_1 = -2.99
β_2 = -0.16
β_3 = 10.77
β_4 = -9.03
β_5 = -16.29
β_6 = 0.26
β_7 = -0.01
β_8 = 0.73
β_9 = -10.22
β_{10} = 0.33
β_{11} = -0.44
β_{12} = 2.17
β_{13} = 0.22
β_{14} = -0.01
β_{15} = 0.14
β_{16} = -0.90

Table 11. Multilevel path analysis findings with anxiety as mediator, COMPASS (2018–2019) (n=58,802)

Outcome	Predictor	*β*	P-value	95% CI
Sleep duration	Income inequality	0.26	0.73	-1.19 to 1.71
	Anxiety score	-2.99	<0.001	-3.11 to -2.87
	Gender (ref=female)	-0.16	0.81	-1.43 to 1.11
	Race (ref=Black and persons of colour)	10.77	<0.001	9.03 to 12.51
	Age	-9.03	<0.001	-9.48 to -8.58
Anxiety score	Income inequality	0.22	<0.001	0.11 to 0.34
Income inequality	% visible minority	0.137	0.002	0.05 to 0.22
	Median after-tax neighbourhood household income	-0.01	0.86	-0.08 to 0.07
	Geographic status (ref=rural)	-0.90	0.59	-4.21 to 2.41

4.4.3.2.2 Gender-stratified

The mediation effect of anxiety score on the association between income inequality and sleep duration appeared stronger in females (β=-4.40, p=0.001, 95% CI=-7.11 to -1.70) than males (β=-2.73, p=0.01, 95% CI=-4.66 to -0.80).

4.4.3.2.2.1 Females

The following global fit measures were obtained for the path model (Figure 7): $\chi2(7)=75.25$, $p<0.001$, TLI=0.998 (close fit), CFI=0.999 (close fit), RMSEA=0.018 (close fit).

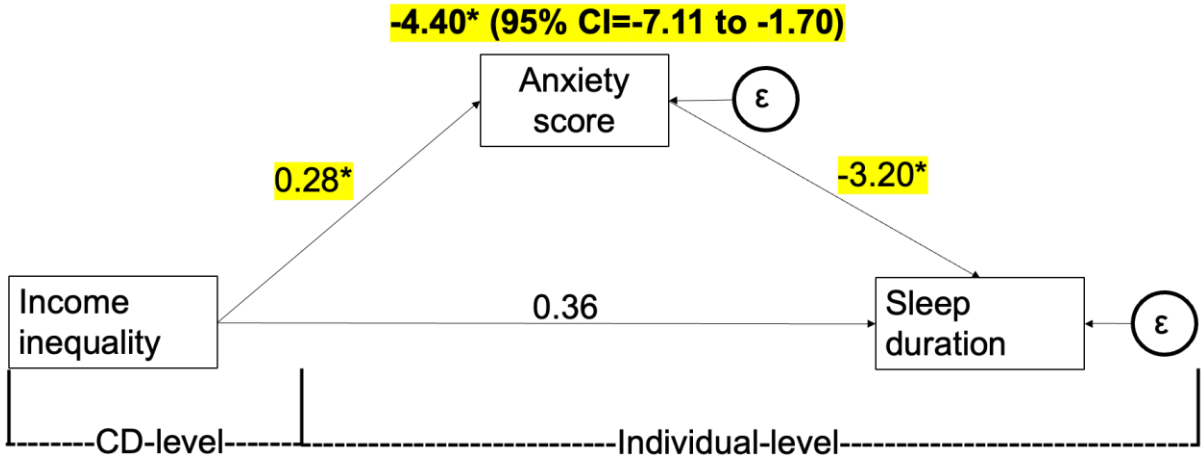

Figure 7. Path model with anxiety as a mediator, female only sample
*p<0.001

The multilevel mediation analysis revealed no significant direct effect of income inequality on sleep duration after adjusting for age and race at the individual- level and % visible minority, median after-tax neighbourhood household income, and geographic status at the CD- level (β=0.36, p=0.68, 95% CI=-1.34 to 2.07).

The mediated path revealed that a 1% increase in income inequality predicted a 0.28 unit increase in anxiety score (p<0.001, 95% CI=0.13 to 0.43). Moreover, a 1 unit increase in anxiety score predicted a 3.20 minute decrease in sleep duration (p<0.001, 95% CI=-3.35 to -3.05). A significant overall indirect effect of income inequality on sleep duration through mediation by anxiety score was observed (β=-4.40, p=0.001, 95% CI=-7.11 to -1.70).

The multilevel path analysis findings are detailed in Table 12.

Table 12. Multilevel path analysis findings with anxiety as mediator, COMPASS (2018-2019), female only sample (n=29,716)

Outcome	Predictor	β	P-value	95% CI
Sleep duration	Income inequality	0.36	0.68	-1.34 to 2.07
	Anxiety score	-3.20	<0.001	-3.35 to -3.05
	Race (ref=Black and persons of colour)	14.35	<0.001	11.89 to 16.81
	Age	-6.75	<0.001	-7.38 to -6.12
Anxiety score	Income inequality	0.28	<0.001	0.13 to 0.43
Income inequality	% visible minority	0.13	0.002	0.05 to 0.22
	Median after-tax neighbourhood household income	-0.01	0.88	-0.08 to 0.07
	Geographic status (ref=rural)	1.44	0.84	-12.83 to 15.71

4.4.3.2.2.2 Males

The following global fit measures were obtained for the path model (Figure 8): $\chi2(7)=73.73$, $p<0.001$, TLI=0.998 (close fit), CFI=0.999 (close fit), RMSEA=0.018 (close fit).

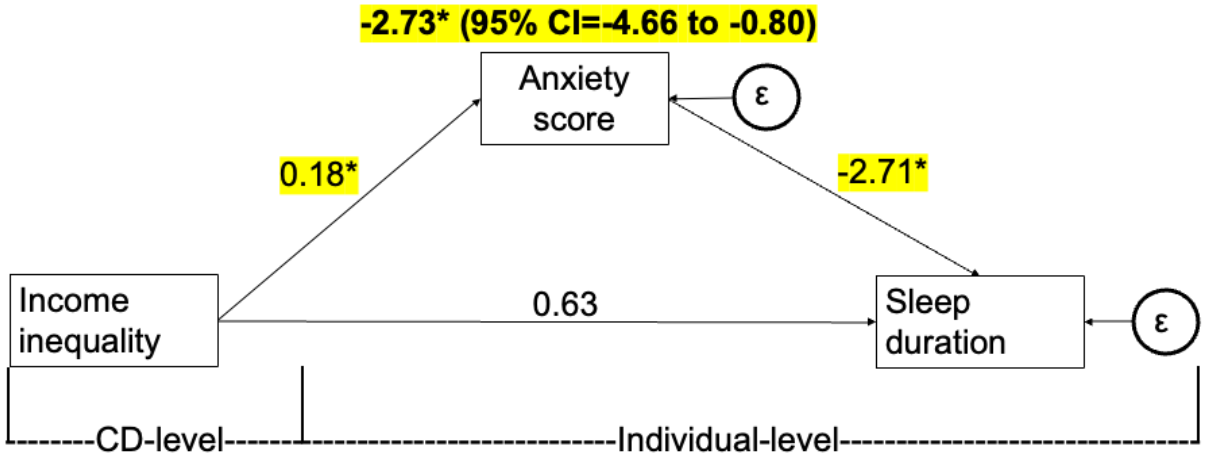

Figure 8. Path model with anxiety as a mediator, male only sample
*p<0.05

The multilevel mediation analysis revealed no significant direct effect of income inequality on sleep duration after adjusting for age and race at the individual- level and % visible minority, median after-

tax neighbourhood household income, and geographic status at the CD- level (β=0.63, p=0.42, 95% CI=-0.91 to 2.17).

The mediated path revealed that a 1% increase in income inequality predicted a 0.18 unit increase in anxiety score (p<0.001, 95% CI=0.09 to 0.26). Moreover, a 1 unit increase in anxiety score predicted a 2.71 minute decrease in sleep duration (p<0.001, 95% CI=-2.90 to -2.53). A significant overall indirect effect of income inequality on sleep duration through mediation by anxiety score was observed (β=-2.73, p=0.01, 95% CI=-4.66 to -0.80).

The multilevel path analysis findings are detailed in Table 13.

Table 13. Multilevel path analysis findings with anxiety as mediator, COMPASS (2018-2019), male only sample (n=29,086)

Outcome	Predictor	*β*	P-value	95% CI
Sleep duration	Income inequality	0.63	0.42	-0.91 to 2.17
	Anxiety score	-2.71	<0.001	-2.90 to -2.53
	Race (ref=Black and persons of colour)	7.27	<0.001	4.83 to 9.71
	Age	-11.31	<0.001	-11.95 to -10.68
Anxiety score	Income inequality	0.18	<0.001	0.09 to 0.26
Income inequality	% visible minority	0.14	0.001	0.05 to 0.23
	Median after-tax neighbourhood household income	-0.01	0.83	-0.08 to 0.07
	Geographic status (ref=rural)	-1.10	0.52	-4.42 to 2.22

4.4.3.3 Multilevel path analysis with social cohesion as a mediator

4.4.3.3.1 Whole sample

The following global fit measures were obtained for the path model (Figure 9): $\chi^2(9)=124.165$, p<0.001, TLI=0.99 (close fit), CFI=1.00 (exact fit), and RMSEA=0.01 (close fit).

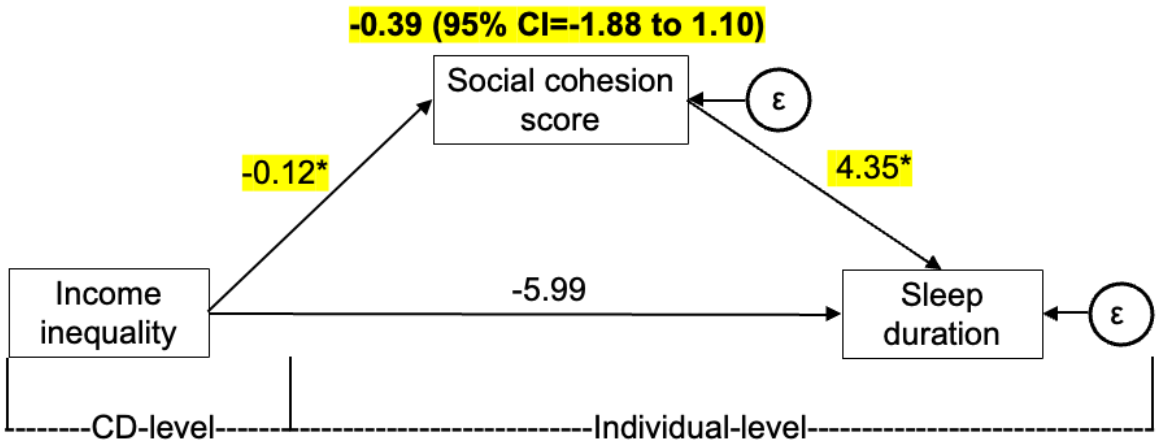

Figure 9. Path model with social cohesion as a mediator
*p<0.05

The multilevel mediation analysis revealed no significant direct effect of income inequality on sleep duration after adjusting for gender, age, and race at the individual-level and % visible minority, median after-tax neighbourhood household income, and geographic status at the CD-level (β=-5.99, p=0.33, 95% CI=-7.85 to 1.53).

The mediated path revealed that a 1% increase in income inequality was associated with a 0.12 unit decrease in social cohesion score (p<0.001, 95% CI=-0.19 to -0.05). Moreover, a 1 unit increase in social cohesion score was associated with a 4.35 minute increase in sleep duration (p<0.001, 95% CI=4.16 to 4.55). The overall indirect effect of income inequality on sleep duration through mediation by social cohesion was not significant (β=-0.39, p=0.61, 95% CI=-1.88 to 1.10).

The multilevel path analysis findings are detailed in Table 14. The equations for the multilevel path analysis can be found below.

Level 1:

$E(sleep\_duration) = \beta_1 social\_cohesion + \beta_2 gender + \beta_3 race + \beta_4 age$

Level 2:

$E(sleep\_duration) = a*\beta_5 social\_cohesion + c*\beta_6 gini\_index + \beta_7 gender + \beta_8 race + \beta_9 age + \beta_{10} median\_income + \beta_{11} visible\_minority + \beta_{12} geographic\_status$

$E(social\_cohesion) = d*\beta_{13} gini\_index$

$E(gini\_index) = e*\beta_{14} median\_income + f*\beta_{15} visible\_minority + g*\beta_{16} geographic\_status$

Indirect and total effects:

ad = a*d
ce = c*e
cf = c*f
cg = c*g

Total=ad + ce + cf + cg

Where:
β_1 = 4.35
β_2 = 7.17
β_3 = 9.48
β_4 = -8.90
β_5 = 3.24
β_6 = -5.99
β_7 = -0.03
β_8 = 0.30
β_9 = -4.48
β_{10} = -0.60
β_{11} = 0.29
β_{12} = 0.66
β_{13} = -0.12
β_{14} = -0.01
β_{15} = 0.13
β_{16} = -0.56

Table 14. Multilevel path analysis findings with social cohesion as mediator, COMPASS (2018–2019) (n=60,991)

Outcome	Predictor	*β*	P-value	95% CI
Sleep duration	Income inequality	-5.99	0.33	-7.85 to1.53
	Social cohesion score	4.35	<0.001	4.16 to 4.55
	Gender (ref=female)	7.17	<0.001	5.97 to 8.37
	Race (ref=Black and persons of colour)	9.48	<0.001	7.77 to 11.18
	Age	-8.90	<0.001	-9.35 to -8.46
Social cohesion score	Income inequality	-0.12	<0.001	-0.19 to -0.05
Income inequality	% visible minority	0.13	0.003	0.05 to 0.22
	Median after-tax neighbourhood household income	-0.01	0.90	-0.08 to 0.07
	Geographic status (reference=rural)	-0.56	0.74	-3.86 to 2.75

4.4.3.3.2 Gender-stratified

The mediation effect of social cohesion on the association between income inequality and sleep duration appeared stronger in females (β=-2.30, p=0.01, 95% CI=-4.06 to -0.53) than males (β=-1.36, p=0.01, 95% CI=-2.43 to -0.30).

4.4.3.3.2.1 Females

The following global fit measures were obtained for the path model (Figure 10): $\chi 2(7)=48.34$, $p<0.001$, TLI=0.999 (close fit), CFI=1.00 (exact fit), RMSEA=0.014 (close fit).

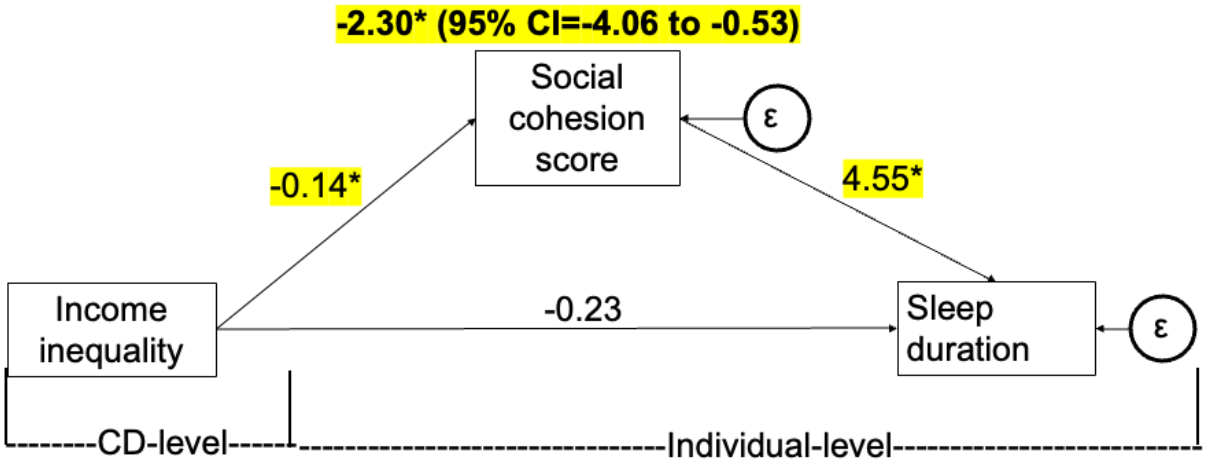

Figure 10. Path model with social cohesion as a mediator, female only sample
*p<0.05

The multilevel mediation analysis revealed no significant direct effect of income inequality on sleep duration after adjusting for age and race at the individual- level and % visible minority, median after-tax neighbourhood household income, and geographic status at the CD- level (β=-0.23, p=0.84, 95% CI=-2.41 to 1.94).

The mediated path revealed that a 1% increase in income inequality predicted a 0.14 unit decrease in social cohesion score (p<0.001, 95% CI=-0.21 to -0.06). Moreover, a 1 unit increase in social cohesion score predicted a 4.55 minute increase in sleep duration (p<0.001, 95% CI=4.27 to 4.83). A significant overall indirect effect of income inequality on sleep duration through mediation by social cohesion was observed (β=-2.30, p=0.01, 95% CI=-4.06 to -0.53).

The multilevel path analysis findings are detailed in Table 15.

Table 15. Multilevel path analysis findings with social cohesion as mediator, COMPASS (2018-2019), female only sample (n=31,083)

Outcome	Predictor	*β*	P-value	95% CI
Sleep duration	Income inequality	-0.23	0.84	-2.41 to 1.94
	Social cohesion score	4.55	<0.001	4.27 to 4.83
	Race (ref=Black and persons of colour)	11.46	<0.001	9.04 to 13.87
	Age	-6.93	<0.001	-7.56 to -6.31
Social cohesion score	Income inequality	-0.14	<0.001	-0.21 to -0.06
Income inequality	% visible minority	0.14	0.001	0.05 to 0.23
	Median after-tax neighbourhood household income	-0.01	0.84	-0.08 to 0.07
	Geographic status (reference=rural)	-1.06	0.53	-4.38 to 2.25

4.4.3.3.2.2 Males

The following global fit measures were obtained for the path model (Figure 11):

$\chi2(7)=37.94$, $p<0.001$, TLI=0.999 (close fit), CFI=1.00 (exact fit), RMSEA=0.012 (close fit).

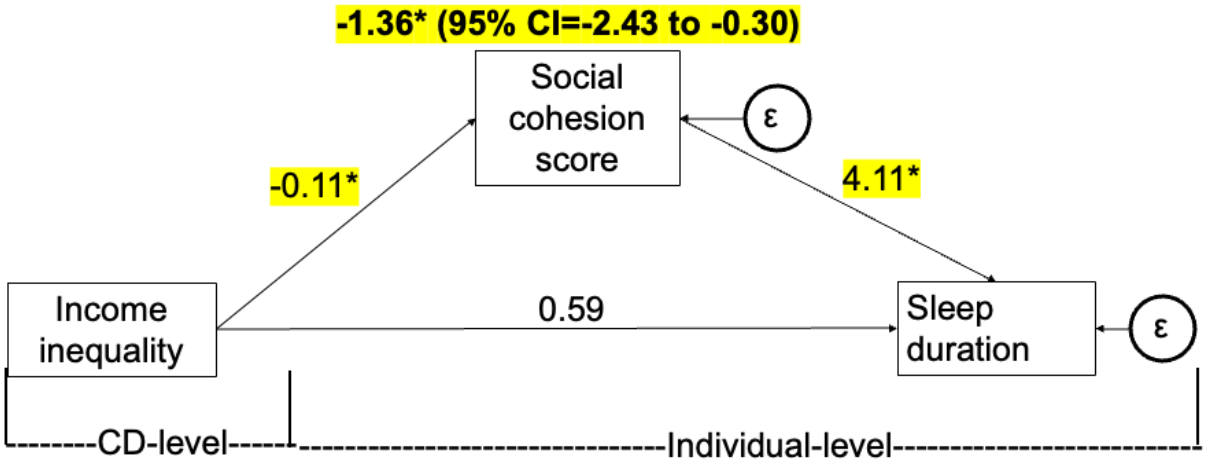

Figure 11. Path model with social cohesion as a mediator, male only sample
*p<0.05

The multilevel mediation analysis revealed no significant direct effect of income inequality on sleep duration after adjusting for age and race at the individual- level and % visible minority, median after-

tax neighbourhood household income, and geographic status at the CD- level (β=0.59, p=0.43, 95% CI=-0.86 to 2.03).

The mediated path revealed that a 1% increase in income inequality predicted a 0.11 unit decrease in social cohesion score (p=0.001, 95% CI=-0.17 to -0.05). Moreover, a 1 unit increase in social cohesion score predicted a 4.11 minute increase in sleep duration (p<0.001, 95% CI=3.83 to 4.38). A significant overall indirect effect of income inequality on sleep duration through mediation by social cohesion was observed (β=-1.36, p=0.01, 95% CI=-2.43 to -0.30).

The multilevel path analysis findings are detailed in Table 16.

Table 16. Multilevel path analysis findings with social cohesion as mediator, COMPASS 2018-2019, male only sample (n=29,908)

Outcome	Predictor	*β*	P-value	95% CI
Sleep duration	Income inequality	0.59	0.43	-0.86 to 2.03
	Social cohesion score	4.11	<0.001	3.83 to 4.38
	Race (ref=Black and persons of colour)	7.62	<0.001	5.22 to 10.02
	Age	-10.95	<0.001	-11.58 to -10.32
Social cohesion score	Income inequality	-0.11	0.001	-0.17 to -0.05
Income inequality	% visible minority	0.15	0.001	0.06 to 0.23
	Median after-tax neighbourhood household income	-0.01	0.80	-0.09 to 0.07
	Geographic status (reference=rural)	-1.38	0.42	-4.71 to 1.95

4.5 Discussion

The objectives of this study were to examine the association between income inequality and sleep duration among Canadian adolescents, how depression, anxiety and social cohesion mediate this relationship, and how these associations differ by gender. Overall, an association between greater income inequality and both lower sleep duration and increased odds of short sleep was observed. This association was more pronounced in females than males. Full mediation effects of depression and anxiety wherein greater income inequality was associated with higher levels of depression and anxiety,

which were in turn, associated with a shorter sleep duration were also found. The mediation effect of depression was slightly stronger in males than females and the mediation effect of anxiety was stronger in females than males. Moreover, a full mediation effect of social cohesion, wherein greater income inequality was associated with a lower level of social cohesion, which was in turn, associated with a shorter sleep duration, was observed in both the female and male stratified samples (with a stronger effect in the former), but not in the whole sample.

These findings were largely consistent with both the hypothesis and prior literature. For example, Clement et al. (2021) found a weak association between income inequality and lower sleep quality among Mexican women[34]. Pabayo et al. (2022) found an association between income inequality and greater odds of inadequate (<7 hours) and very inadequate (<5 hours) sleep among American adults, especially among women[74]. The current study suggest that these associations are also relevant among Canadian adolescents.

One potential reason for the observed heterogeneity in association between income inequality and sleep duration between males and females, wherein a stronger association was observed among females, is because females are more vulnerable to income inequality-related decreases in social cohesion[109], a risk factor for depression and anxiety[71,110]. This observed heterogeneity aligns with existing research that suggests that in general, the health of females is more responsive to income inequality than that of males. In addition to sleep, income inequality impacts on depression and physical activity have also been found to be more detrimental among females than males[71].

The observed mediation effects of depression and anxiety were also consistent with Pabayo et al.'s (2022) finding of the number of poor mental health days mediating the association between income inequality and odds for inadequate (<7 hours) and very inadequate (<5 hours) sleep[74]. While Pabayo et al. (2022) found a slight attenuation of the association between income inequality and lower sleep duration when the mental health mediator was added to the model (partial mediation)[74], no direct association between income inequality and sleep duration in the presence of the depression or anxiety mediator (full mediation) was observed. Several reasons for the discrepancy in study findings can be speculated. Firstly, Pabayo et al. (2022) used the Baron and Kenny method[74] for mediation while path analysis was used for this investigation. Path analysis is argued to be more methodically sound than

Baron and Kenny given its ability to directly test the indirect path of interest. While both mediators pertained to mental health, they were not identical. Pabayo et al. (2022) measured the number of poor mental health days[74] while in the current study, depressive symptoms were measured using the CESD and anxiety symptoms were measured using the GAD7. Moreover, the COMPASS sample was substantially younger (age range=12 to 19 years) than that in Pabayo et al. (2022) (age range=18 to 65 years)[74]. Teens are known to be more biologically and socially susceptible to sleep deprivation than adults.

Strengths

This is one of the first studies to examine the mechanisms linking income inequality and sleep duration. This investigation was based on a sample of Canadian adolescents, an unexplored demographic in existing studies on income inequality and sleep. This study used the CESD and GAD7, well validated instruments for measuring depressive symptoms and anxiety symptoms, respectively. The passive consent protocols and large sample size present in this study may have improved effect size estimates and increased statistical power (the capacity to correctly identify statistically significant associations). Statistical power may have also been increased by using a continuous measure for the sleep outcome in addition to dichotomous.

Limitations

Limitations of the current study include the use of data collected by self-report, resulting in potential social desirability bias, and thus greater or lower sleep duration estimates. However, this was likely mitigated by the anonymity of the in-person surveys in which students were not asked to disclose their names. Self-reporting bias may have also occurred in the form of recall bias as relative to objective measures such as actigraphy, sleep duration tends to be overestimated in self-report. Moreover, the sleep measure in COMPASS only asked about average sleep duration and did not differentiate between weekday and weekend sleep nor capture other important indicators of healthy sleep such as sleep quality. Findings may have also been subject to selection bias. Students who obtain a few hours of sleep tend to have poorer health in general and consequent poorer attendance. Such students are less likely to have been present for the in-person surveys, potentially leading to an underestimation of association. Selection bias may have also occurred in the form of convenience sampling, thereby lowering external

validity. Residual confounding may have been present in this study as covariates were chosen based on prior literature and their availability in the COMPASS system. The COMPASS system did not have information on household/individual-level income, a predictor of adolescent sleep duration[45]. The cross-sectional nature of this study prevents the inference of any temporal or causal association. As the impacts of income inequality may take time to come into effect, the cross-sectional study design may have contributed to some of the null findings in the multilevel path models.

4.6 Conclusion

In sum, this study provides initial insights on the association between income inequality and sleep duration in Canadian teens. Observed associations were identified between greater income inequality and lower sleep duration and increased odds of short sleep (<8 hours) vs. normal sleep (8-10 hours), especially among female teens. Full mediation effects of depression and anxiety wherein greater income inequality was associated with higher levels of depression and anxiety, which were in turn, associated with a shorter sleep duration were also found. The mediation effect of depression was slightly stronger in males than females and the mediation effect of anxiety was stronger in females than males. Moreover, a full mediation effect of social cohesion, wherein greater income inequality was associated with a lower level of social cohesion, which was in turn, associated with a shorter sleep duration, was observed in both the female and male stratified samples (with a stronger effect in the former), but not in the whole sample. Future studies should examine the association between income inequality and sleep longitudinally and with natural experiments (e.g., cash transfers), to gain a more in depth understanding of the mechanisms of this association. They should also explore this relationship using other demographics (e.g., young children) and countries. Overall. the results provide further reasoning for policy makers to focus on decreasing income inequality to improve the health of society members, such as through progressive taxation policies. Findings suggest that reducing societal income gaps may improve adolescent sleep especially in those attending school in high income inequality areas, females, and those experiencing depression and anxiety. This research also highlights the need for tailored approaches to improving adolescent sleep. Greater investment and research in school-based sleep health promotion should be done in areas with greater income inequality.

Chapter 5: Conclusion

The purpose of this thesis was to examine the association between income inequality and sleep duration in adolescents. The primary objectives were to (1) Summarize and synthesize existing literature on the association between absolute and relative income inequality measures through a narrative review, to provide context for the analyses. (2) Examine the association between income inequality and sleep duration among Canadian adolescents and how this association varies across gender, using multilevel modeling analysis. (3) Assess how depression, anxiety and social cohesion mediate the relationship between income inequality and sleep duration among Canadian adolescents and how this association varies across gender, using multilevel path analysis. The latter two objectives were met using a cross-sectional analysis of data from Wave 7 (year 2018-2019; n=74,501) of the Cohort on Obesity, Marijuana use, Physical activity, Alcohol use, Smoking, and Sedentary behavior (COMPASS) study, a prospective longitudinal study, that links data from teens attending secondary schools across Ontario, Alberta, Quebec, British Columbia, and Nunavut.

The narrative review included 30 articles and were based on diverse study populations, neighbourhood SES and income inequality measures, and sleep duration and quality outcomes. Findings of included articles were mixed but most pointed to an association between greater neighbourhood SES and greater sleep duration and quality and greater income inequality and lower sleep duration and quality. This review also highlighted gaps and limitations in prior work including social desirability bias, recall bias, selection bias, and residual confounding. No prior study had examined the association between income inequality and sleep in adolescents or in a Canadian setting.

In the analytic portion of the thesis (chapter 4), an association between greater income inequality and both lower sleep duration and increased odds of short sleep was observed. This association was more pronounced in females than males. A full mediation effect of depression and anxiety wherein greater income inequality was associated with higher levels of depression and anxiety, which were in turn, associated with a shorter sleep duration was also found. The mediation effect of depression was slightly stronger in males than females and the mediation effect of anxiety was stronger in females than males. Moreover, a full mediation effect of social cohesion, wherein greater income inequality was associated with a lower level of social cohesion, which was in turn, associated with a shorter sleep

duration, was observed in both the female and male stratified samples (with a stronger effect in the former), but not in the whole sample. Overall. the results provide further reasoning for policy makers to focus on decreasing income inequality to improve the health of society members, such as through progressive taxation policies. Findings suggest that reducing societal income gaps may improve adolescent sleep especially in those attending school in high income inequality areas, females, and those experiencing depression and anxiety. This research also highlights the need for tailored approaches to improving adolescent sleep. Greater investment and research in school-based sleep health promotion should be done in areas with greater income inequality.

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Appendices

Search Strategies

Pubmed

("Poverty Areas"[MeSH] or "income inequality" or "income gap" or "income disparity" or "income inequity" or "income distribution" or "distribution of income*" or "economic inequality" or "economic gap" or "economic disparity" or "economic inequity" or "economic distribution" or "neighborhood income" or "neighborhood poverty" or "neighborhood socioeconomic" or "neighborhood SES" or "neighborhood econom*" or "neighborhood disadvantage*" or "neighborhood distress" or "neighborhood deprivation" or "neighborhood level income" or "neighborhood level poverty" or "neighborhood level socioeconomic" or "neighborhood level SES" or "neighborhood level econom*" or "neighborhood level disadvantage*" or "neighborhood level distress" or "neighborhood level deprivation" or "neighborhood-level income" or "neighborhood-level poverty" or "neighborhood-level socioeconomic" or "neighborhood-level SES" or "neighborhood-level econom*" or "neighborhood-level disadvantage*" or "neighborhood-level distress" or "neighborhood-level deprivation" or "neighbourhood income" or "neighbourhood poverty" or "neighbourhood socioeconomic" or "neighbourhood SES" or "neighbourhood econom*" or "neighbourhood disadvantage*" or "neighbourhood distress" or "neighbourhood deprivation" or "neighbourhood level income" or "neighbourhood level poverty" or "neighbourhood level socioeconomic" or "neighbourhood level SES" or "neighbourhood level econom*" or "neighbourhood level disadvantage*" or "neighbourhood level distress" or "neighbourhood level deprivation" or "neighbourhood-level income" or "neighbourhood-level poverty" or "neighbourhood-level socioeconomic" or "neighbourhood-level SES" or "neighbourhood-level econom*" or "neighbourhood-level disadvantage*" or "neighbourhood-level distress" or "neighbourhood-level deprivation" or "disadvantaged neighborhood*" or "disadvantaged neighbourhood*" or "community income" or "community poverty" or "community socioeconomic" or "community SES" or "community econom*" or "community disadvantage*" or "community distress" or "community deprivation" or "community level income" or "community level poverty" or "community level socioeconomic" or "community level SES" or "community level econom*" or "community level disadvantage*" or "community level distress" or "community level deprivation" or "community-level income" or "community-level poverty" or "community-level socioeconomic" or "community-level SES" or "community-level econom*" or "community-level disadvantage*" or "community-level distress" or "community-level deprivation" or "school level poverty" or "school level socioeconomic" or "school level SES" or "school level econom*" or "school level deprivation" or "school-level poverty" or "school-level socioeconomic" or "school-level SES" or "school-level econom*" or "school-level deprivation" or "area income" or "area poverty" or "area socioeconomic" or "area SES" or "area econom*" or "area disadvantage*" or "area distress" or "area deprivation" or "area level income" or "area level poverty" or "area level socioeconomic" or "area level SES" or "area level econom*" or "area level disadvantage*" or "area level distress" or "area level deprivation" or "area-level income" or "area-level poverty" or "area-level socioeconomic" or "area-level SES" or "area-level econom*" or "area-level disadvantage*" or "area-level distress" or "area-level deprivation" or gini or "concentration curve" or "concentration curves" or "Socio-Economic Indicators For Areas" or SEIFA) AND ("Sleep Deprivation"[MeSH] or "Sleep Hygiene"[MeSH] or "Sleep"[MeSH] or "Sleep Quality"[MeSH] or sleep* or napp*)

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((MH "Poverty Areas") OR (TX "income inequality") OR (TX "income gap") OR (TX "income disparity") OR (TX "income inequity") OR (TX "income distribution") OR (TX "distribution of income*") OR (TX "economic inequality") OR (TX "economic gap") OR (TX "economic disparity") OR (TX "economic inequity") OR (TX "economic distribution") OR (TX "neighborhood income") OR (TX "neighborhood poverty") OR (TX "neighborhood socioeconomic") OR (TX "neighborhood SES") OR (TX "neighborhood econom*") OR (TX "neighborhood disadvantage*") OR (TX "neighborhood distress") OR (TX "neighborhood deprivation") OR (TX "neighborhood level income") OR (TX "neighborhood level poverty") OR (TX "neighborhood level socioeconomic") OR (TX "neighborhood level SES") OR (TX "neighborhood level econom*") OR (TX "neighborhood level disadvantage*") OR (TX "neighborhood level distress") OR (TX "neighborhood level deprivation") OR (TX "neighborhood-level income") OR (TX "neighborhood-level poverty") OR (TX "neighborhood-level socioeconomic") OR (TX "neighborhood-level SES") OR (TX "neighborhood-level

econom*") OR (TX "neighborhood-level disadvantage*") OR (TX "neighborhood-level distress") OR (TX "neighborhood-level deprivation") OR (TX "neighbourhood income") OR (TX "neighbourhood poverty") OR (TX "neighbourhood socioeconomic") OR (TX "neighbourhood SES") OR (TX "neighbourhood econom*") OR (TX "neighbourhood disadvantage*") OR (TX "neighbourhood distress") OR (TX "neighbourhood deprivation") OR (TX "neighbourhood level income") OR (TX "neighbourhood level poverty") OR (TX "neighbourhood level socioeconomic") OR (TX "neighbourhood level SES") OR (TX "neighbourhood level econom*") OR (TX "neighbourhood level disadvantage*") OR (TX "neighbourhood level distress") OR (TX "neighbourhood level deprivation") OR (TX "neighbourhood-level income") OR (TX "neighbourhood-level poverty") OR (TX "neighbourhood-level socioeconomic") OR (TX "neighbourhood-level SES") OR (TX "neighbourhood-level econom*") OR (TX "neighbourhood-level disadvantage*") OR (TX "neighbourhood-level distress") OR (TX "neighbourhood-level deprivation") OR (TX "disadvantaged neighborhood*") OR (TX "disadvantaged neighbourhood*") OR (TX "community income") or (TX "community poverty") OR (TX "community socioeconomic") OR (TX "community SES") OR (TX "community econom*") OR (TX "community disadvantage*") OR (TX "community distress") OR (TX "community deprivation") OR (TX "community level income") OR (TX "community level poverty") OR (TX "community level socioeconomic") OR (TX "community level SES") OR (TX "community level econom*") OR (TX "community level disadvantage*") OR (TX "community level distress") OR (TX "community level deprivation") OR (TX "community-level income") OR (TX "community-level poverty") OR (TX "community-level socioeconomic") OR (TX "community-level SES") OR (TX "community-level econom*") OR (TX "community-level disadvantage*") OR (TX "community-level distress") OR (TX "community-level deprivation") OR (TX "school level poverty") OR (TX "school level socioeconomic") OR (TX "school level SES") OR (TX "school level econom*") OR (TX "school level deprivation") OR (TX "school-level poverty") OR (TX "school-level socioeconomic") OR (TX "school-level SES") OR (TX "school-level econom*") OR (TX "school-level deprivation") OR (TX "area income") OR (TX "area poverty") OR (TX "area socioeconomic") OR (TX "area SES") OR (TX "area econom*") OR (TX "area disadvantage*") OR (TX "area distress") OR (TX "area deprivation") OR (TX "area level income") OR (TX "area level poverty") OR (TX "area level socioeconomic") OR (TX "area level SES") OR (TX "area level econom*") OR (TX "area level disadvantage*") OR (TX "area level distress") OR (TX "area level deprivation") OR (TX "area-level income") OR (TX "area-level poverty") OR (TX "area-level socioeconomic") OR (TX "area-level SES") OR (TX "area-level econom*") OR (TX "area-level disadvantage*") OR (TX "area-level distress") OR (TX "area-level deprivation") OR (TX gini) OR (TX "concentration curve") OR (TX "concentration curves") OR (TX "Socio-Economic Indicators For Areas") OR (TX SEIFA)) AND ((MH "Sleep Deprivation") OR (MH "Sleep Hygiene") OR (MH "Sleep") OR (TX sleep*) OR (TX napp*))

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(INDEXTERMS("Poverty Areas") or TITLE-ABS("income inequality") or TITLE-ABS("income gap") or TITLE-ABS("income disparity") or TITLE-ABS("income inequity") or TITLE-ABS("income distribution") or TITLE-ABS("distribution of income*") or TITLE-ABS("economic inequality") or TITLE-ABS("economic gap") or TITLE-ABS("economic disparity") or TITLE-ABS("economic inequity") or TITLE-ABS("economic distribution") or TITLE-ABS("neighborhood income") or TITLE-ABS("neighborhood poverty") or TITLE-ABS("neighborhood socioeconomic") or TITLE-ABS("neighborhood SES") or TITLE-ABS("neighborhood econom*") or TITLE-ABS("neighborhood disadvantage*") or TITLE-ABS("neighborhood distress") or TITLE-ABS("neighborhood deprivation") or TITLE-ABS("neighborhood level income") or TITLE-ABS("neighborhood level poverty") or TITLE-ABS("neighborhood level socioeconomic") or TITLE-ABS("neighborhood level SES") or TITLE-ABS("neighborhood level econom*") or TITLE-ABS("neighborhood level disadvantage*") or TITLE-ABS("neighborhood level distress") or TITLE-ABS("neighborhood level deprivation") or TITLE-ABS("neighborhood-level income") or TITLE-ABS("neighborhood-level poverty") or TITLE-ABS("neighborhood-level socioeconomic") or TITLE-ABS("neighborhood-level SES") or TITLE-ABS("neighborhood-level econom*") or TITLE-ABS("neighborhood-level disadvantage*") or TITLE-ABS("neighborhood-level distress") or TITLE-ABS("neighborhood-level deprivation") or TITLE-ABS("neighbourhood income") or TITLE-ABS("neighbourhood poverty") or TITLE-ABS("neighbourhood socioeconomic") or TITLE-ABS("neighbourhood SES") or TITLE-ABS("neighbourhood econom*") or TITLE-ABS("neighbourhood disadvantage*") or TITLE-ABS("neighbourhood distress") or TITLE-ABS("neighbourhood deprivation") or

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PsycINFO

((Index Terms: (Poverty Areas)) OR (abstract: (income inequality)) OR (abstract: (income gap)) OR (abstract: (income disparity)) OR (abstract: (income inequity)) OR (abstract: (income distribution)) OR (abstract: (distribution of income*)) OR (abstract: (economic inequality)) OR (abstract: (economic gap)) OR (abstract: (economic disparity)) OR (abstract: (economic inequity)) OR (abstract: (economic distribution)) OR (abstract: (neighborhood income)) OR (abstract: (neighborhood poverty)) OR (abstract: (neighborhood socioeconomic)) OR (abstract: (neighborhood SES)) OR (abstract: (neighborhood econom*)) OR (abstract: (neighborhood disadvantage*)) OR (abstract: (neighborhood distress)) OR (abstract: (neighborhood deprivation)) OR (abstract: (neighborhood level income)) OR (abstract: (neighborhood level poverty)) OR (abstract: (neighborhood level socioeconomic)) OR (abstract: (neighborhood level SES)) OR (abstract: (neighborhood level econom*)) OR (abstract: (neighborhood level disadvantage*)) OR (abstract: (neighborhood level distress)) OR (abstract: (neighborhood level deprivation)) OR (abstract: (neighborhood-level income)) OR (abstract: (neighborhood-level poverty)) OR (abstract: (neighborhood-level socioeconomic)) OR (abstract: (neighborhood-level SES)) OR (abstract: (neighborhood-level econom*)) OR (abstract: (neighborhood-level disadvantage*)) OR (abstract: (neighborhood-level distress)) OR (abstract: (neighborhood-level deprivation)) OR (abstract: (neighbourhood income)) OR (abstract: (neighbourhood poverty)) OR (abstract: (neighbourhood socioeconomic)) OR (abstract: (neighbourhood SES)) OR (abstract: (neighbourhood econom*)) OR

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Table 1A. Individual-level correlation matrix

	Age	BMI	Physical activity time
Age	-	0.21	-0.03
BMI	0.21	-	0.01
Physical activity time	-0.03	0.01	-

Table 2A. CD-level correlation matrix

	Income inequality	Median after-tax neighbourhood household income	% visible minority	% low income households	Population size
Income inequality	-	0.08	0.69	0.81	0.70
Median after-tax neighbourhood household income	0.08	-	0.45	-0.06	0.24
% visible minority	0.69	0.45	-	0.70	0.92
% low income households	0.81	-0.06	0.70	-	0.80
Population size	0.70	0.24	0.92	0.80	-

Table 3A. Cross-sectional multilevel associations between income inequality and sleep duration (continuous) in Canadian secondary school students, including physical activity time and BMI as covariates (n=45,418)

Variables	Sleep duration								
	Crude			Adjusted			Adjusted + interaction		
	β	P-value	95% CI	β	P-value	95% CI	β	P-value	95% CI
Intercept	652.13	<0.001	561.74 to 742.65	743.80	<0.001	665.58 to 821.77	778.10	<0.001	699.50 to 856.55
CD-level									
Gini index	-5.65	<0.001	-8.16 to -3.15	-3.48	0.001	-5.52 to -1.44	-4.389	<0.001	-6.45 to -2.34
Median after-tax neighbourhood household income (in $1000 units)				-0.39	0.13	-0.89 to 0.12	-0.39	0.12	-0.90 to 0.11
% visible minority				-0.35	0.26	-0.98 to 0.27	-0.35	0.26	-0.98 to 0.27
Geographic status (ref=rural)									
Urban				30.14	0.01	8.51 to 51.77	30.02	0.08	8.43 to 51.62
Individual-level									
Gender (ref: female)									
Male				7.83	<0.001	6.44 to 9.22	-63.56	<0.001	-6.45 to -2.34
Gini interaction							1.94	<0.001	1.40 to 2.48
Race (ref= Black and persons of colour)									
White				11.20	<0.001	9.20 to 13.20	11.12	<0.001	9.12 to 13.12
Spending money (ref= $0)									
$1 to $5				-3.49	<0.001	-5.41 to -1.56	-3.50	<0.001	-5.43 to -1.57
$6 to $10				0.19	0.84	-1.58 to 1.95	0.23	0.80	-1.53 to 1.99
$11 to $20				0.79	0.44	-1.22 to 2.79	0.76	0.45	-1.24 to 2.77
$21 to $40				-0.01	1.00	-2.08 to 2.07	-0.05	0.96	-2.12 to 2.02
$41 to $100				-2.95	0.01	-5.13 to -0.77	-2.94	0.01	-5.12 to -0.76
>$100				-0.18	0.86	-2.21 to 1.84	-0.28	0.79	-2.30 to 1.75
Age				-9.08	<0.001	-9.65 to -8.51	-9.08	<0.001	-9.65 to -8.51
Physical activity time				0.04	<0.001	0.03 to 0.05	0.03	<0.001	0.03 to 0.05
BMI				-1.16	<0.001	-1.35 to -0.96	0.04	<0.001	-1.37 to -0.98

Table 4A. Cross-sectional multilevel associations between income inequality and odds for obtaining short sleep (<8 hours) in Canadian secondary school students, including physical activity time and BMI as covariates (n=45,418)

Variables	**<8 hours sleep duration (ref: 8-10 hours sleep)**								
	Crude			**Adjusted**			**Adjusted + interaction**		
	OR	**P-value**	**95% CI**	**OR**	**P-value**	**95% CI**	**OR**	**P-value**	**95% CI**
Intercept	0.01	<0.001	0.001 to 0.05	0.001	<0.001	0.0001 to 0.004	0.0003	<0.001	4.571424e-05 0.0017
CD-level									
Gini index	1.15	<0.001	1.08 to 1.21	1.09	<0.001	1.04 to 1.14	1.12	<0.001	1.06 to 1.17
Median after-tax neighbourhood household income (in $1000 units)				1.01	0.16	1.00 to 1.02	1.01	0.15	1.00 to 1.02
% visible minority				1.01	0.20	1.00 to 1.02	1.01	0.20	1.00 to 1.02
Geographic status (ref=rural)									
Urban				0.53	0.01	0.33 to 0.87	0.54	0.01	0.33 to 0.87
Individual-level									
Gender (ref: female)									
Male				0.82	<0.001	0.79 to 0.86	6.23	<0.001	3.52 to 11.04
Gini interaction							0.95	<0.001	0.93 to 0.96
Race (ref=Black and persons of colour)									
White				0.75	<0.001	0.71 to 0.79	0.75	<0.001	0.71 to 0.79
Spending money (ref=$0)									
$1 to $5				1.09	0.001	1.03 to 1.16	1.09	0.001	1.04 to 1.16
$6 to $10				0.99	0.62	0.94 to 1.04	0.99	0.59	0.94 to 1.04
$11 to $20				0.99	0.82	0.94 to 1.05	0.99	0.83	0.94 to 1.05
$21 to $40				0.98	0.45	0.92 to 1.04	0.98	0.47	0.92 to 1.04
$41 to $100				1.03	0.30	0.97 to 1.10	1.03	0.30	0.97 to 1.10
>$100				1.02	0.50	0.96 to 1.08	1.02	0.44	0.97 to 1.08
Age				1.27	<0.001	1.24 to 1.29	1.27	<0.001	1.25 to 1.29
Physical activity time				1.00	<0.001	1.00 to 1.00	1.00	<0.001	1.00 to 1.00
BMI				1.02	<0.001	1.02 to 1.03	1.03	<0.001	1.02 to 1.03

Table 5A. Multilevel path analysis findings with depression as mediator, COMPASS (2018–2019), including physical activity time and BMI as covariates (n=46,460)

Outcome	Predictor	*β*	P-value	95% CI
Sleep duration	Income inequality	0.08	0.92	-1.54 to 1.70
	Depression score	0.18	<0.001	0.08 to 0.27
	Gender (ref=female)	-0.95	0.17	-2.30 to 0.40
	Race (ref= Black and persons of colour)	10.68	<0.001	8.76 to 12.60
	Age	-8.71	<0.001	-9.21 to -8.21
	Physical activity time	0.03	<0.001	0.02 to 0.04
	BMI	-0.87	<0.001	-1.06 to -0.69
Depression score	Income inequality	0.18	<0.001	0.08 to 0.27
Income inequality	% visible minority	0.14	<0.001	0.06 to 0.23
	Median after-tax neighbourhood household income	-0.01	0.80	-0.09 to 0.07
	Geographic status (ref=rural)	-1.34	0.43	-4.67 to 1.98

Table 6A. Multilevel path analysis findings with anxiety as mediator, COMPASS (2018–2019), including physical activity time and BMI as covariates (n=46,595)

Outcome	Predictor	*β*	P-value	95% CI
Sleep duration	Income inequality	0.36	0.62	-1.07 to 1.79
	Anxiety score	-3.03	<0.001	-3.16 to -2.90
	Gender (ref=female)	-1.30	0.07	-2.69 to 0.09
	Race (ref= Black and persons of colour)	12.58	<0.001	10.64 to 14.52
	Age	-8.63	<0.001	-9.13 to -8.12
	Physical activity time	0.04	<0.001	0.03 to 0.05
	BMI	-0.98	<0.001	-1.17 to -0.80
Anxiety score	Income inequality	0.21	<0.001	0.09 to 0.32
Income inequality	% visible minority	0.14	<0.001	0.05 to 0.23
	Median after-tax neighbourhood household income	-0.01	0.84	-0.08 to 0.07
	Geographic status (ref=rural)	-1.07	0.53	-4.38 to 2.25

Table 7A. Multilevel path analysis findings with social cohesion as mediator, COMPASS (2018–2019), including physical activity time and BMI as covariates (n=48,238)

Outcome	Predictor	*β*	P-value	95% CI
Sleep duration	Income inequality	-0.25	1.00	-2.76 to 2.74
	Social cohesion score	4.15	<0.001	3.93 to 4.36
	Gender (reference=female)	6.66	<0.001	5.34 to 7.97
	Race (ref= Black and persons of colour)	10.97	<0.001	9.06 to 12.88
	Age	-8.50	<0.001	-9.00 to -8.00
	Physical activity time	0.03	0.001	0.02 to 0.04
	BMI	-1.04	<0.001	-1.22 to -0.85
Social cohesion score	Income inequality	-0.11	0.001	-0.18 to -0.05
Income inequality	% visible minority	0.13	<0.001	0.04 to 0.21
	Median after-tax neighbourhood household income	-0.003	0.97	-0.08 to 0.07
	Geographic status (ref=rural)	-0.30	0.86	-3.64 to 3.03