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Income inequality and comorbid overweight/obesity and depression among a large sample of Canadian secondary school students: The mediator effect of social cohesion

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A B S T R A C T

Background: Comorbid overweight/obesity (OWO) and depression is emerging as a public health problem among adolescents. Income inequality is a structural determinant of health that independently increases the risk for both OWO and depression among youth. However, no study has examined the association between income inequality and comorbid OWO and depression or tested potential mechanisms involved. We aimed to identify the association between income inequality and comorbid OWO and depression and to test whether social cohesion mediates this relationship.

Methods: We used data from the 2018–2019 Cannabis, Obesity, Mental health, Physical activity, Alcohol, Smoking and Sedentary behavior (COMPASS) project. Our sample was composed of 46,171 adolescents from 136 schools distributed in 43 census divisions in 4 provinces in Canada (Ontario, Alberta, British Columbia, and Quebec). Gender-stratified multilevel path analyses models were used to examine whether income inequality (Gini coefficient) was associated with comorbid OWO and depression and whether the association was mediated by school connectedness, a proxy measure for social cohesion.

Results: The direct effect between income inequality and OWO-depression comorbidity was not significant. However, income inequality was significantly associated with increased risk of comorbidity via social cohesion. One standard deviation increase in the Gini coefficient was associated with a 9% and 8% increase in the odds of comorbidity in females (OR=1.09; 95% CI=1.03, 1.16) and males (OR=1.08; 95% CI=1.03, 1.13).

Conclusion: Policies aimed at reducing income inequality, and interventions to improve social cohesion, may contribute to reducing the risk of OWO-depression comorbidity among adolescents.

1. Introduction

Overweight/obesity (OWO) and depression in adolescents are major public health concerns. Recent school-based studies conducted from a convenience sample of Canadian adolescents (12–19 years) found that 40% of students report clinically-relevant symptoms of depression and/or anxiety (Williams et al., 2021) while 34.6% are at risk of overweight/obesity (Hunter et al., 2023). In addition to OWO and depression discretely being major health concerns, they frequently coexist among individuals, posing even greater threats to health (Fu et al., 2023). Comorbid OWO and depression is rapidly increasing in different populations with studies reporting of prevalence estimates ranging from 3.7% to 16% (Khanolkar & Patalay, 2021; Melton et al., 2021). Beyond the independent impact of depression and OWO on a person's health and wellbeing, individuals living with the comorbidity experience increased risk of cardiovascular diseases, functional disability, psychological distress, diabetes mellitus and higher health care utilization (Lin et al., 2022; Qin et al., 2023). Epidemiological and clinical studies have shown a plausible bidirectional causal relationship between OWO and depression due to shared psychosocial, metabolic and genetic mechanisms that contribute to the pathophysiology of the comorbidity (Milaneschi et al., 2019). This is corroborated by evidence that shows that 55% of individuals with obesity are at high risk of developing depression over time, while 58% of individuals with an early onset of depression are at high risk of developing obesity at some point in their lifetime (Luppino et al., 2010). Therefore, understanding the predictors

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of comorbidity may help in guiding public health interventions.

The epidemiology of the comorbid OWO and depression is an emerging area in research, with limited population-level studies available. Overall, comorbidity has been commonly reported among females (Scott et al., 2008), with some studies demonstrating heterogeneity of effects across females and males (Rajan & Menon, 2017). Comorbidity is also likely to develop in adolescence as this has been shown to be a critical period for the onset of OWO and mental health disorders (Bann et al., 2018; Patalay & Gage, 2019). Several other socio-demographic groups have also been reported to be associated with comorbidity, including individuals from low-income households, ethnic minority groups, frequent alcohol consumers, and individuals with low rates of physical activity (Chae et al., 2022; Haregu et al., 2020; Melton et al., 2021; Preiss et al., 2013). The influence of area-level factors on the occurrence of comorbidity has rarely been studied. Only two studies have investigated the role of socio-economic status and community size. Comorbidity was found to be common among socio-economically disadvantaged populations (Haregu et al., 2020) while there was no significant association reported in relation to community size (Chae et al., 2022). As such, there is an apparent gap in the current literature regarding structural determinants of comorbid OWO and depression.

One structural determinant of health that may be linked with comorbidity is income inequality, i.e., the disproportionate distribution of income in a specific group or area (Kawachi & Kennedy, 1999). Income inequality has been associated with adolescent BMI (Hunter et al., 2023; Lowe et al., 2023) and mental health (Benny et al., 2022; Pabayo et al., 2016) separately. Currently, there are no studies that have explored the relationship between income inequality and comorbid OWO and depression. However, comorbidity literature suggests that diseases could co-occur due to 'a shared pattern of influence' (Fu et al., 2023; Valderas et al., 2009). Therefore, it can be postulated that income inequality, by virtue of being a common risk factor for both depressive symptoms and OWO (Lowe et al., 2023; Pabayo et al., 2016), could also be associated with higher risk of comorbidity.

1.1. Theoretical background

Drawing from the social determinants of health framework, income inequality can be conceptualized as a structural determinant that can directly or indirectly influence adolescent health in various ways (Goodman, 2008; Herge et al., 2013; Viner et al., 2012). The seminal works of Kawachi and colleagues (Kawachi & Kennedy, 1999; Wilkinson, 1999) identify three mechanisms through which income inequality may potentially influence health outcomes. First is the social comparison pathway that suggests that negative health outcomes are results of invidious comparison of social status (Kawachi & Kennedy, 1999). This mechanism posits that societies have status hierarchies in which individual's compete for status to increase their social standing within the society (Prag et al., 2013; Wilkinson, 1999). Failure to achieve the societal 'ideal status' invites negative appraisals to one's status which leads to chronic stress that negatively affects ones health (Dickerson & Kemeny, 2004; Prag et al., 2013). Second is the neo-materialist pathway that proposes that income distribution shapes investments in human capital, health and social infrastructure (Lynch et al., 2004). Societies with high inequalities are thus characterised with underinvestment in human capital and other public infrastructure due to limited collective resources to facilitate such investments (Lynch et al., 2004; Prag et al., 2013). This in turn will shape the quality and access of health-promoting public infrastructure such as schools, health care services and occupational opportunities that can help to boost individuals social mobility (Lynch et al., 2004).

The third pathway that is complementary to the neo-materialist mechanism is the social cohesion and social capital pathways. Literature suggests that income inequality erodes social cohesion and social capital (Kawachi & Kennedy, 1999). Social cohesion is key in building trust and cooperation that in turn buffer the community from behaviors that may be deleterious to their health (ibid.). Therefore, declines in social cohesion could lead to the feeling of social isolation and individual's disconnection from the community (Santini et al., 2020). Potential consequences of suppressed communal engagements may be an increase in depressive symptoms (Pabayo et al., 2016), decreases in community physical activity and inadequate access to healthy diets (Clément et al., 2021) which may synergistically lead to comorbidity. Social cohesion within the school environment could be playing an important role in shaping adolescent health since the majority of adolescents spend a substantial amount of their time in schools. Cohesion in terms of a bonding and feeling a sense of belonging in school has been shown to be a protective factor against negative health outcomes and delinquent behaviors (Nasir et al., 2011; Quader et al., 2022; Zhang et al., 2023). A proxy measure that has been used in previous research among school-going adolescents to capture social cohesion is school connectedness (Benny et al., 2022). Certain aspects of the commonly used school connectedness scale such as fair treatment, closeness and feelings of belonging (McNeely et al., 2002; Patte et al., 2021) resonate well with the concepts of mutual trust and a sense of belonging engendered in the social cohesion construct (Kawachi & Subramanian, 2014; Pei et al., 2020), hence making school connectedness a valid proxy for social cohesion.

The effect of income inequality in shaping health outcomes is by no means similar across all population subgroups. Females, relative to males, have been found to show higher sensitivity to income inequality in various health outcomes including weight gain, sedentary lifestyle, smoking and depression (Diez-Roux et al., 2000; Pabayo et al., 2016; Patel et al., 2018). Cultural gender norms, including sociocultural appearance ideals, may offer explanations as to why such disproportionate effects are likely to occur. Income inequality may heighten attention to other social hierarchies and comparisons, including by weight and gender, and the perceived need to conform to gendered norms. For example, females residing in areas with high income inequality are more likely to be stigmatized and discriminated based on their weight when compared to males (Li, 2024), and weight stigma is known to predict both weight gain and depression (Greenleaf et al., 2017). Additionally, female adolescents are also known to internalize their problems as a coping mechanism for stressful environments (Hankin et al., 2007; Pabayo et al., 2016). Given that internalizing problems have been shown to elevate the risk of both OWO (Preiss et al., 2013) and depression (Zahn-Waxler et al., 2000), there is a high probability that comorbidity will disproportionately affect female adolescents relative to their male counterparts.

To our knowledge, no prior studies have investigated the association between income inequality and comorbidity. Therefore, this study aims to test this relationship empirically; the objectives are: 1) To identify the association between income inequality and OWO and depression comorbidity; and 2) to investigate whether social cohesion (school connectedness) mediates the relationship between income inequality and comorbidity. We hypothesized that census division income inequality will have a direct effect with comorbidity. Our direct effect hypothesis relies on two mechanisms. i.e., the invidious social comparison and neo-materialist mechanisms. Given that in this study we were unable to test the potential mediation of these two mechanisms, we anticipated that these effects would be reflected on the direct association between income inequality and comorbidity. We further hypothesized that social cohesion, would significantly mediate the relationship between census division income inequality and comorbidity. Our indirect effect hypothesis is pegged on the mechanism underlying the impact of income inequality in eroding social cohesion (Benny et al., 2022; Kawachi & Kennedy, 1999). Finally, we hypothesized that the direct and/or mediated relationship between income inequality and comorbidity would be stronger in females than males as females internalizing behaviours in response to stressful environments (Pabayo et al., 2016) may elevate their risk of comorbidity.

2. Methods

This study used secondary data from the Cannabis, Obesity, Mental health, Physical activity, Alcohol, Smoking and Sedentary behavior (COMPASS) project. Established in 2012, the COMPASS project is an ongoing prospective cohort study that collects survey data annually from secondary schools and students attending those schools (grades 9 to 12) (Leatherdale et al., 2014). COMPASS covers four Canadian provinces: Ontario, Alberta, British Columbia, and Quebec. COMPASS utilizes a convenience sampling approach targeting high schools that permit use of active information–passive consent protocols (Hompson-Haile et al., 2013). All study protocols for the COMPASS project were approved by the University of Waterloo Office of Research Ethics (#30118), University of Alberta Ethics (#RE0050375) and the appropriate school board committees of participating schools (Leatherdale et al., 2014). Further details on the COMPASS study methods and protocols are available online (www.compass.uwaterloo.ca).

The current study utilized cross-sectional data from the 2018–2019 school year (wave 7). In wave 7 of the COMPASS project, full school samples of students completed a paper-and-pencil questionnaire during class time. The analysis was limited to participants who had complete data on all variables of interest. Subsequently, the case complete COMPASS data was linked to an area-level (Census divisions) dataset obtained from the 2016 Canadian Census that contained measures of income inequality and other covariates of interests. Census divisions are geographically demarcated areas situated between municipalities and provinces in Canada (Statistics Canada, 2018). They are established to facilitate regional planning and are used by government to conduct the periodic census (Statistics Canada, 2018). Out of 74,501 students that participated in the 2018–2019 survey, 46,733 (62.7%) from 136 schools nested within 43 census divisions in 4 provinces in Canada (Ontario, Alberta, British Columbia, and Quebec) had complete data and thus formed our analytic sample for this study.

2.1. Measures

2.1.1. Outcome

Risk of OWO was assessed using body mass index (BMI) calculated as weight in kilograms divided by height in squared meters. Before calculating BMI values, all reported measures for height and weight were multiplied by sex-specific correction factors for females (height=1.00116 and weight=1.04779) and males (height=1.00058 and weight=1.02998) to correct for biases associated with self-reported anthropometric values (Leatherdale & Laxer, 2013). BMI values were transformed into age- and sex-standardized z-scores (WHO, 2007b) and classified based on the World Health Organization's (WHO) guidelines as follows: underweight (<-2), normal weight (−2 to ≤1), overweight (>1 to ≤2) and obesity (>2) (WHO, 2007a). Participants with implausible z-BMI scores of <-5 or >5 were excluded from the study. Additionally, we also excluded underweight participants (<2%) since they did not form an adequate sample size for estimating statistical differences.

Participants' depressive symptoms were measured using a 10-item Center for Epidemiologic Studies Depression Scale Revised (CESD -R). The CESD-R scale involves assessing the frequency of occurrence of 10 depressive symptoms over the previous week (Cronbach's α=0.82) (Van Dam & Earleywine, 2011). Plausible scores range from 0 to 30 with higher scores indicative of more frequent depressive symptoms. A binary variable was constructed to assess whether participants had clinically-relevant depression symptoms (CESD-R score ≥10) or not (CES-D score <10) (Van Dam & Earleywine, 2011).

The outcome of interest, comorbidity, was created by combining the BMI and depression variables as follows: i) Neither classified as having OWO nor depression (reference group); ii) classified as having OWO only; iii) depression only; and iv) comorbid (i.e., classified as having both OWO and depression).

2.1.2. Exposure

Income inequality was assessed using the Gini coefficient. The Gini coefficient was computed at the Census Division (CD) level using household income data from the 2016 Canadian Census. A Lorenz curve was created by plotting the cumulative proportion of the household income against the cumulative proportion of the population (Benny et al., 2023). The Gini coefficient was calculated by dividing the area between the line of equality and the Lorenz curve (A) by the total area beneath the perfect line of equality (A + B) (Fig. 1). A detailed computation of the Gini coefficient can be found elsewhere (Dorfman, 1979). Values of the Gini coefficient ranged from 0 (equal distribution) to 1 (unequal distribution). The Gini coefficient variable was z-transformed for ease of interpretation of the results.

2.1.3. Mediating variable

This study used the school connectedness scale as a proxy measure of the social cohesion construct. Derived from previous studies on school going adolescents (McNeely et al., 2002), COMPASS surveys use a 6-item scale to assess school connectedness (Cronbach's α=0.82). Students were asked to provide responses on a 4-point Likert scale to the following six statements: "I feel close to people at my school", "I feel I am part of my school", "I am happy to be at my school", "I feel the teachers at my school treat me fairly", "I feel safe in my school", and "Getting good grades is important to me". Responses were summed (scores between 6 and 24) and higher scores were indicative of greater connectedness. In line with previous research (Benny et al., 2022), we excluded the item "Getting good grades is important to me" from the connectedness scale as it is not reflective of the social cohesion construct espoused in this study. Therefore, our new measure consisted of five items with score between 4 and 20.

2.1.4. Covariates

In COMPASS surveys, respondents were asked to report whether they were female or male. Literature suggests that the 'female' or 'male' responses in surveys may refer to biological (sex) and social (gender) identity (Johnson et al., 2009). In the present study, we used gender (henceforth) since the study focuses on social processes that may lead to

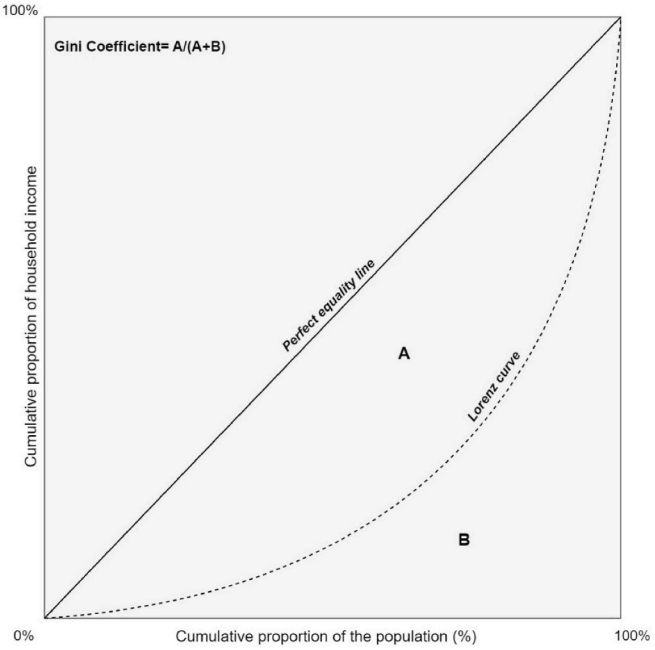

Fig. 1. Graphical depiction of Gini coefficient calculation.

health inequities. Covariates at the individual level included age (12–19 years), ethnicity (white or people of colour), the amount of money that the student has available to spend on themselves on a weekly basis ($0, $1-$5, $6-$10, $11-$20, $21-$40, $41-$100, >$100, and don't know), alcohol consumption (none, <once per month, monthly, weekly, not stated), and amount of time spent in vigorous physical activity per day (<60 min per day, ≥60 min per day, not stated). At the CD-level, the covariates included provinces (Alberta, British Columbia, Ontario, and Quebec), median after-tax household income and population size.

2.1.5. Statistical analysis

Initial analysis involved estimating the prevalence of OWO and depression. Descriptive statistics were calculated by comparing the prevalence of the outcome variable across the exposure, mediator, and the covariates. Our main analysis involved the use of a multilevel (two-level) path analysis approach to examine the hypothesized effect of income inequality on comorbidity. Multilevel models were selected due to the hierarchical nature of the dataset where students and schools were nested within CDs, whereas the path analysis framework was suitable because it allows for the examination of both the direct and indirect (mediated) associations of the exposure.

Data cleaning and coding of variables were done using STATA v16.0, while path analysis was performed using Mplus v8.8. With the study outcome being a nominal variable, multinomial regression would have been the ideal model for this analysis. However, multinomial regression models within the framework of path analysis have not been validated. Therefore, we used a two-level logistic regression model, where level-1 was composed of individual level variables and level-2 being measurements at the CD. For computational efficiency with Mplus (Muthén et al., 2011), our outcome variable was split into a set of three binary outcomes as follows: 1) Neither OWO or depression vs. OWO-depression comorbidity; 2) Neither OWO or depression vs. OWO only; and 3) Neither OWO or depression vs. depression only. Furthermore, the analysis was stratified by gender to examine whether the effect of income inequality was heterogeneous between females and males. All models were fitted using the maximum likelihood robust (MLR) estimator, which is robust to non-normality. For ease of interpretation, the regression coefficient estimates were exponentiated and interpreted as odds ratio (OR) at 5% significance level.

2.1.5.1. Assessing model fit. Model fitness for path analysis models is commonly assessed by a combination of relative indices such as Tucker-Lewis index (TLI) and absolute fit indices such as Standardized Root Mean Square Residuals (SRMR). However, when using multilevel models, these fit indices are not available. In such cases, the use of likelihood ratio tests (nested models) and information criteria (non-nested models) have been recommended (Curran et al., 2010). Therefore, we assessed model fitness using the log-likelihood tests. This was performed by comparing the unadjusted mediated models (model 1) to the fully adjusted mediated model (model 2), with the models with a higher value indicating adequate fit.

3. Results

3.1. Descriptive statistics

The prevalences of overweight and obesity were 21.6% and 8.0% among females and 23.7% and 12.6% among males, respectively. The prevalence of underweight was <2% in each gender group. The estimated prevalence of depression was 46.2% among females and 25.5% among males. After excluding the underweight participants (n=562), the final analytic sample was composed of 46,171 adolescents from 136

Table 1
Descriptive characteristics of the study population.

Individual Characteristics	Neither OWO- Depression	OWO Only	Depression Only	Comorbid OWO and Depression
Frequency n=46,171	20,043	9541	10,735	5852
Age, mean (std)	15.19 (±1.49)	15.12 (±1.47)	15.51 (±1.36)	15.49 (±1.39)
Gender, %				
Male	10,911 (54.44)	6112 (64.06)	3508 (32.68)	2291 (39.15)
Female	9132 (45.56)	3429 (34.94)	7227 (67.32)	3561 (60.85)
Ethnicity, %				
White	15,072 (75.20)	7053 (73.92)	7311 (68.10)	3891 (66.49)
People of colour	4971 (24.80)	4971 (26.08)	3424 (31.90)	1961 (33.51)
Weekly Spending Money, %				
$0	2711 (13.53)	1374 (14.40)	1498 (13.95)	895 (15.29)
$1-$5	1054 (5.26)	460 (4.82)	587 (5.47)	298 (5.09)
$6-$10	1320 (6.59)	585 (6.13)	682 (6.35)	334 (5.71)
$11-$20	2347 (11.71)	1036 (10.86)	1282 (11.94)	656 (11.21)
$21-$40	2271 (11.33)	1114 (11.68)	1245 (11.60)	650 (11.11)
$41-$100	2595 (12.95)	1221 (12.80)	1535 (14.30)	804 (13.74)
>$100	4105 (20.48)	2127 (22.29)	2286 (21.29)	1424 (24.33)
Don't know	3640 (18.16)	1624 (17.02)	1620 (15.09)	791 (13.52)
Alcohol Consumption, %				
None	9527 (47.53)	4397 (46.09)	3902 (36.35)	2060 (35.20)
<Once per month	4323 (21.57)	2056 (21.55)	2602 (24.24)	1419 (24.25)
Monthly	4512 (22.51)	2177 (22.82)	3086 (28.75)	1688 (28.84)
Weekly	1592 (7.94)	870 (9.12)	1104 (10.28)	661 (11.30)
Not stated	89 (0.5)	41 (0.43)	41 (0.38)	24 (0.41)
Physical Activity, %				
<60 min per day	11,923 (59.49)	5413 (56.73)	6812 (63.46)	3517 (60.10)
≥60 min per day	7912 (39.48)	4047 (42.42)	3823 (35.61)	2272 (38.82)
Not stated	208 (1.04)	81 (0.85)	100 (0.93)	63 (1.08)
Social Cohesion	16.03 (±2.59)	15.93 (±2.71)	13.77 (±2.87)	13.51 (±2.95)
Income Inequality (Gini)	0.37 (±0.03)	0.37 (±0.03)	0.37 (±0.03)	0.37 (±0.03)
Provinces				
Alberta	860 (4.29)	463 (4.85)	512 (4.77)	347 (5.93)
British Columbia	2660 (13.27)	968 (10.15)	1793 (16.70)	740 (12.65)
Ontario	7466 (37.25)	4077 (42.73)	4666 (43.47)	2901 (49.57)
Quebec	9057 (45.19)	4033 (42.27)	3764 (35.06)	1864 (31.85)
Median after-tax income	59006.14 (±8901.52)	58850.40 (±8714.41)	60204.00 (±8728.77)	60207.80 (±8653.38)
Population Size	546565.60 (±667367.30)	464146.80 (±576972.30)	613023.60 (±724,566.00)	514797.80 (±642240.90)

schools distributed in 43 census divisions (Table 1). Nearly half of the adolescents had neither OWO or depression (43.4%), 20.7% had OWO alone, 23.3% had depression alone and 12.6% had comorbid OWO-depression. Among those with comorbidity, the majority were females (60.9%), white students (66.5%), those with available weekly spending money of >$100 (24.3%), alcohol consumers (64.4%), students who undertook <60 min of vigorous physical activity per day (60.1%) and residents of Ontario (49.6%).

3.2. Path analysis

3.2.1. Comorbidity

In relation to model fitness, the log-likelihood values for covariate adjusted gender-stratified models (female=−36641.964, males=−37134.965) were higher than those of crude mediated models (female=−36752.922, males=−37218.505) indicating an adequate fit for our final models. Fig. 2 presents the gender stratified unstandardized coefficients of the direct and indirect paths in the multilevel path analysis models. For either gender, the direct effect was not statistically significant. However, the indirect (mediated) effects were statistically significant. A unit increase in social cohesion score was associated with lower risk of comorbid OWO-depression in females (β=−0.34; 95% CI=−0.36, −0.32) and males (β=−0.29; 95% CI=−0.31, −0.27) (Table S1, Supplementary document). However, this protective effect was nullified by the effect of income inequality on social cohesion where a one-standard deviation (SD) increases in Gini coefficient resulted to a decrease in social cohesion in females (β=−0.25; 95% CI=−0.43, −0.08) and males (β=−0.25; 95% CI=−0.41, −0.10) respectively. In sum, relative to students with neither condition, one-SD increase in Gini coefficient via the social cohesion mediated pathway was associated with a 9% and 8% increase in the odds of comorbid OWO-depression in females (OR=1.09; 95% CI=1.03, 1.16) and males (OR=1.08; 95% CI=1.03, 1.13) respectively (Table 2).

3.2.2. Comparison between overweight/obesity alone, depression alone and comorbidity

Path analyses findings for the depression alone and OWO alone groups are presented in the supplemental document (Tables S2-S5 and Figs. S1 and S2). The effects observed among the depression alone group were like that of the comorbid OWO and depression, albeit with smaller effect sizes. One-SD increase in Gini was indirectly (via school connectedness) associated with higher odds of depression in females (OR=1.08; 95% CI=1.03, 1.14) and males (OR=1.07; 95% CI=1.02, 1.11), compared to a group of students with neither condition (Table S2). For the OWO alone group, the indirect effect of income inequality was only observed among females where a one-SD increase in Gini resulted to a modest increase in the odds of OWO (OR=1.01; 95% CI=1.00, 1.02) (Table S4).

4. Discussion

In this multilevel path analysis study, we found that there was no direct association between income inequality and comorbidity. However, income inequality was indirectly associated with comorbid OWO and depression via the social cohesion mediated pathway. In our stratified analyses, we observed that the regression coefficients of this association was slightly stronger among females than in males. Finally, we also found that the observed significant indirect effect of income inequality was comparable to that of individuals with depression only, although the regression coefficients for comorbidity was slightly stronger.

There are various mechanisms through which income inequality may contribute to adverse health outcomes. Findings from this study suggests that erosion of social cohesion (Kawachi & Kennedy, 1999) (school connectedness) could be one of the pathway through which income inequality increases the risk of OWO-depression comorbidity among school going adolescents. School connectedness has been shown to be an important factor that influences adolescents' health and well-being, including conferring protection against depression and excess weight gain (Quader et al., 2022; Zhang et al., 2023). However, residential

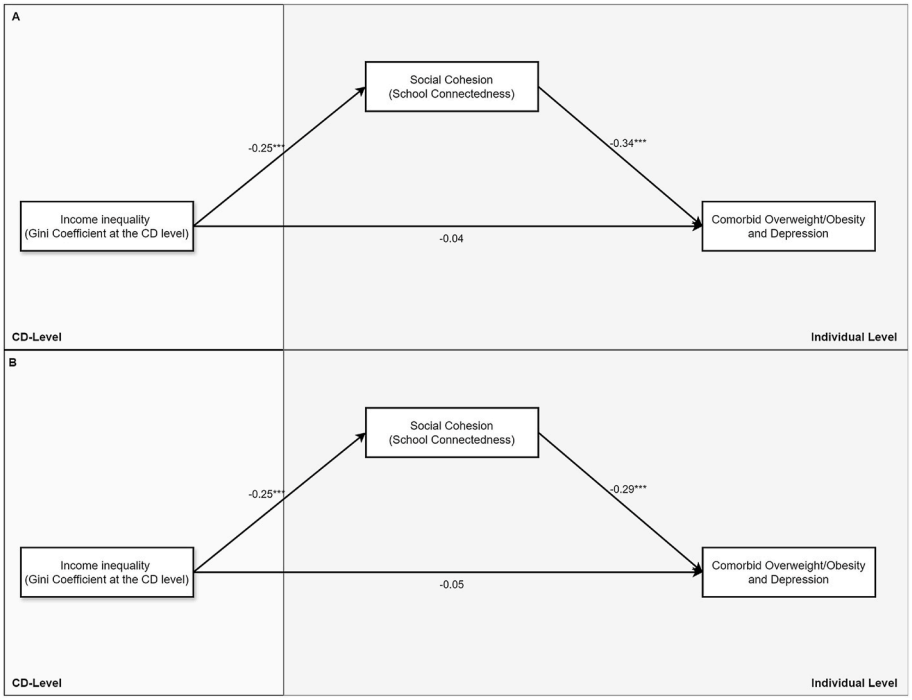

Fig. 2. Path diagrams (A-Females and B-Males) displaying the unstandardized beta coefficients of the multilevel path analysis between CD-Level income inequality and comorbid overweight/obesity and depression as mediated by social cohesion: COMPASS 2018–2019.
*=$p<0.05$, **=$p<0.01$, ***=$p<0.001$

Table 2
Multi-level path analysis results of comorbid overweight/obesity and depression by gender.

	Variable	Female OR (95% CI)	Male OR (95% CI)
Direct Effect	**Income Inequality**	0.96 (0.89 1.03)	1.05 (0.92 1.19)
Indirect Effect	**Income Inequality → Social Cohesion**	**1.09 (1.03 1.16)**	**1.08 (1.03 1.13)**
Covariates	***Individual level***		
	Age	0.94 (0.91 0.98)	1.02 (0.97 1.09)
	Ethnicity		
	White	1.00	1.00
	People of colour	1.53 (1.23 1.90)	1.51 (1.32 1.72)
	Weekly spending money		
	$0	1.00	1.00
	$1 to $5	0.98 (0.80 1.19)	0.89 (0.74 1.06)
	$6 to $10	0.90 (0.76 1.08)	0.69 (0.57 0.84)
	$11 to $20	0.85 (0.71 1.02)	0.91 (0.76 1.09)
	$21 to $40	0.78 (0.64 0.95)	0.91 (0.79 1.05)
	$41 to $100	0.81 (0.69 0.94)	0.79 (0.67 0.94)
	>$100	0.90 (0.78 1.04)	0.83 (0.71 0.97)
	Don't know	0.70 (0.59 0.83)	0.73 (0.64 0.85)
	Alcohol consumption		
	None	1.00	1.00
	<Once per month	1.53 (1.38 1.68)	1.26 (1.12 1.42)
	Monthly	1.89 (1.60 2.24)	1.62 (1.36 1.92)
	Weekly	1.92 (1.52 2.44)	1.75 (1.39 2.20)
	Not stated	0.87 (0.38 1.98)	1.50 (0.74 3.02)
	Physical activity		
	<60 min per day	1.00	1.00
	>60 min per day	1.11 (1.02 1.21)	0.89 (0.79 1.00)
	Not stated	0.88 (0.61 1.28)	0.91 (0.56 1.49)
	CD Level		
	Provinces		
	Ontario	1.00	1.00
	Alberta	1.05 (0.79 1.39)	0.90 (0.60 1.35)
	British Columbia	0.87 (0.73 1.04)	0.89 (0.69 1.16)
	Quebec	0.64 (0.57 0.72)	0.55 (0.43 0.70)
	Median after tax income	0.95 (0.93 0.97)	1.00 (0.92 1.09)
	Population size	0.98 (0.96 1.00)	0.99 (0.97 1.00)

areas with unequal distribution of income are unlikely to provide conditions that promote connectedness. Communities affected with large income inequalities are likely to experience disruptions in social and political systems, which in turn may lead to increases in crime, anxiety and stress (Pop et al., 2013). Furthermore, highly unequal areas are characterized with underinvestment in social infrastructure and human capital, limiting access to resources that are crucial in promoting human health (Kawachi & Kennedy, 1999; Kawachi & Subramanian, 2014). Such constraints could be reflected in inadequate funding of school boards and thus school programs that promote connectedness, such as extracurricular activities, safety programs, counselling services, and training of educators on emerging challenges such as mental health (Nasir et al., 2011), are likely to be scarce in unequal areas. Therefore, the risk of comorbidity is likely to be high in such divested environments.

The effects of income inequality seemed to be slightly pronounced in female than male students. This finding is in line with previous studies that have shown higher risk of comorbidity among females (Chae et al., 2022; Lin et al., 2022), which is likely driven by the high prevalence of depression in females relative to males. This gender difference may be due to differences in coping mechanisms that may expose females more to high-risk behaviors. Girls dealing with stress are likely to withdraw socially and are more likely to seek solace in unhealthy eating, accompanied with a physically inactive lifestyle (Mooreville et al., 2014; Quader et al., 2022). Indulgence in such risky behaviors is likely to increase the risk of comorbidity.

Additionally, this study also found that the regression coefficients of income inequality on comorbidity was slightly stronger compared to that of income inequality and depression alone across the gender groups. This is not surprising as previous studies have also reported an exaggerated effect in relation to the risk factors of comorbid OWO and depression. For instance, Khanolkar and Patalay (2021) using pooled data from two British national birth cohorts found that adolescents (16 years) classified as belonging to a disadvantaged childhood social class (i.e., father's social class being partly skilled and unskilled) were associated with a much higher risk of comorbid OWO and mental-ill health (RRR=2.04; 95% CI=1.54, 2.72) over and above the risk of OWO (RRR=1.39; 95% CI=1.21, 1.58) and mental-ill health (RRR=1.36; 95% CI=1.22, 1.51) separately. From our analysis, it is clear that this elevated risk of comorbidity is highly driven by the erosion of school connectedness. This suggests that deterioration of school connectedness due to high income inequality could be impacting a common pathway for both OWO and depression that cumulatively leads to high risk of comorbidity. However, with lack of literature to back our hypothesis, we recommend future studies to investigate the sequential precedence of mechanisms that underlies the relationship between school connectedness and comorbidity.

Contrary to our hypothesis, this study did not find any significant direct association between income inequality and comorbidity. Our anticipation was that a residual effect from the two hypothesized mechanisms (social comparison and neo-materialist pathways) that were untested in this study would have been reflected in this direct path. The reasons as to why we observed this null finding are highly speculative. First, the study findings may be suggesting that in this specific population of Canadian adolescents, the relationship between income inequality and comorbid OWO and depression is potentially not mediated by social comparison and/or neo-materialism mechanisms. Second, the mechanisms underlying the influence of income inequality on health outcome are not mutually exclusive. For example, there is a reciprocal relationship between neo-materialism and social cohesion in that in schools that have inadequate investments in co-curricular activities, human capital and other social programs may as well contain students who feel less connected and accepted within their school environments (Benny, 2023; Jenson & Saint-Martin, 2003; Kawachi & Subramanian, 2014). Therefore, there is a likelihood that the hypothesized effect of the neo-materialism was usurped by the school connectedness pathway. However, these explanations are not certain given the data limitations we have with the current study. Future studies using longitudinal data may be able to offer better clarity of the influence of the untested mechanisms.

The emergence of comorbidity among adolescents indicates that siloed approach of public health interventions aimed at reducing the risk of OWO and depression separately may be ineffective in reducing health morbidities. Integrated approaches that target root causes of comorbid conditions are likely to be more effective (Khanolkar & Patalay, 2021). Findings from this study indicate that policies that focus on the reduction of census-division income inequality may have a long-lasting impact in addressing comorbidity since such 'upstream' factors also influence the operation of 'downstream' risk factors. Development of

economic policies that aim to achieve fair distribution of income such as progressive taxation and social policies geared towards reducing income inequities such as equitable educational opportunities can contribute substantially in reducing the risk of comorbidity (Patel et al., 2018). Additionally, our results also reveal that certain aspects of the school environment can be leveraged with the aim of promoting adolescent health. Measures leverage on the power of school connectedness in creating social trust and reducing social isolation in areas characterized with unequal distribution of income can contribute to the reduction of the risk of comorbidity.

Several limitations should be considered when interpreting the findings from this study. First, even though we had a large sample size, nearly one third of survey participants did not report their weight, height and depressive symptoms values (Doggett et al., 2022) hence the exclusion of these participants in our analysis may have introduced some bias in our findings. To assess the extent of this potential bias, we conducted two exploratory tests: 1) we compared the proportions of the non-response and complete case samples across the levels of each covariates using chi-square and 2) we conducted a logistic regression predicting the odds of non-response versus case complete, using the study covariates as the predictors. Our findings suggested that non-respondents were more likely to be younger (<15 years), identified as an ethnic minority, had low weekly spending money (5 dollars or less) and those who had never taken alcohol. However, proportions of non response sample compared to the case complete sample was not substantially different across the levels of the covariates, hence we believe that the findings of our study are still useful despite these biases. Second, since COMPASS surveys use convenience sampling, our findings cannot be fully generalized to the entire Canadian population. Third, the study used cross sectional data and therefore causal inferences cannot be made based on our findings. Finaly, our findings may also be biased due to residual confounding since we were unable to fully adjust for known confounders such as house income.

In conclusion, this study found that income inequality via social cohesion (school connectedness) is associated with higher risk of comorbid OWO and depression among school going adolescents, with females being slightly more affected than males. Moreover, adolescents attending schools in areas with high income inequality are potentially at higher risk of developing comorbidity than OWO or depression alone. Future studies can build from this study by investigating this relationship using longitudinal data to determine the impact of areas income inequality on comorbidity from a life course dimension.

Ethical statement

This study used data from the Cannabis, Obesity, Mental health, Physical activity, Alcohol, Smoking and Sedentary behavior (COMPASS) project. The current study was approved by the University of Waterloo Office of Research Ethics (#30118), the University of Alberta Ethics (#RE0050375) as well as the school board committees of participating schools. However, the decision to submit the manuscript and the views reported in this paper are those of the authors and does not represent the official views of the University of waterloo or University of Alberta.

CRediT authorship contribution statement

Jason Mulimba Were: Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis, Conceptualization. **Stephen Hunter:** Writing – review & editing, Methodology, Conceptualization. **Karen A. Patte:** Writing – review & editing, Project administration, Investigation, Funding acquisition. **Scott T. Leatherdale:** Writing – review & editing, Project administration, Investigation, Funding acquisition. **Roman Pabayo:** Writing – review & editing, Supervision, Project administration, Methodology, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

COMPASS study data is available upon request through completion and approval of an online form: https://uwaterloo.ca/compass-system/information-researchers/data-usage-application The datasets used during the current study are available from the corresponding author on reasonable request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssmph.2024.101710.

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