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Original quantitative research

Gender differences in the longitudinal association between multilevel latent classes of chronic disease risk behaviours and body mass index in adolescents

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Abstract

Introduction: Few studies have assessed the relationship between chronic disease risk behaviours and body mass index (BMI) in a longitudinal, sex/gender-specific context. This study used gender-specific analyses to assess the extent to which chronic disease risk behaviour latent classes are associated with BMI and weight status at follow-up.

Methods: Longitudinal data from 4510 students in Grades 9 to 12, tracked from 2013–2015, who participated in the COMPASS study were used to assess gender differences in the lagged association between previously determined latent classes (of physical activity and substance use) with BMI using multilevel mixed-effects models. Our multilevel regression models assessed the association between two latent classes, active experimenters and inactive non-using youth, with BMI when stratified by gender.

Results: Male inactive non-substance-using youth were associated with a 0.29 higher continuous BMI (95% CI: 0.057, 0.53) and odds of overweight/obesity increased by 72% (OR = 1.72, 95% CI: 1.2, 2.4) for binary BMI at follow-up relative to active youth who experiment with substance use. No significant associations were detected in females.

Conclusion: Over time, physical activity has a protective role on BMI in male youth. Both substance use and physical inactivity should be addressed in obesity prevention efforts. Gender stratification in analyses is also important since females and males have different contributing factors to increases in BMI.

Keywords: *chronic disease risk behaviours, substance use, physical activity, sex, gender, BMI, obesity, overweight, adiposity*

Highlights

- Approximately 20% of youth who were overweight/obese were in the normal weight body mass index (BMI) category 1 year later.
- Male inactive non-substance users had increases in BMI and increases in the odds of becoming overweight/obese relative to their active substance-using peers. No associations were identified in females.
- Physical activity seems to play a role in males in prospectively maintaining BMI despite their engagement with substance use.

Introduction

Overweight and obesity are escalating in youth: 27% of Canadian children were classified as overweight or obese in 2013.[1] Childhood obesity tracks into adulthood, increasing the risk of adult chronic diseases.[2,3] That body mass index (BMI) decreases in youth over time (in males more than in females), but not in adults, highlights the importance of prevention efforts directed at this age group.[1,4,5]

Despite public health prevention and intervention efforts, BMI is increasing in certain populations, including in Canadian youth.[5,6] Overweight/obesity have many determining factors, of which chronic disease risk behaviours (CDRB; e.g. physical inactivity, binge drinking) are major contributors.[7,8] Laxer et al.[6] used longitudinal data (2012–2014) from the Cohort Study on Obesity, Marijuana Use, Physical Activity, Alcohol Use, Smoking and Sedentary Behaviour (COMPASS) to assess the effect of 15 CDRB (including physical inactivity, dietary choices and sedentary and substance use behaviours) at baseline (via latent classes) on BMI at concurrent years, while controlling for gender. The authors found that BMI increased by an average of 0.61 units per year; however, the researchers were unable to identify a specific latent class that had higher risk of increasing BMI.

Devis-Devis et al.[4] and Jackson & Cunningham[9] did not find an association between CDRB latent classes and obesity, and recommended further investigation.[4] A limitation of these two studies is that they only included physical activity, sedentary behaviours and diet,[4,10] despite evidence that substance users (i.e. smokers and marijuana users) are most likely to have

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overweight/obesity relative to their non-substance-using counterparts.[11-13]

Another notable shortcoming of previous research has been the lack of assessment of the role of sex/gender in the association between CDRB and obesity.[6,9,14,15] For instance, Laxer et al. reported that males were associated with a higher increase in BMI, but did not conduct sex/gender-specific modelling.[6] Published studies have demonstrated sex/gender differences in BMI[16,17] and in CDRB engagement—including physical inactivity and substance use[17,18], indicating that sex/gender-specific models are warranted. Research has also found that physical inactivity and substance use play roles in youth overweight and obesity,[14,15,17,19,20] showing the importance of incorporating substance use, as well as sex/gender-stratified analyses, into research of obesity in youth.

Given the notable gaps in obesity literature, Hammami et al.[17] identified latent classes of CDRB (physical inactivity, binge drinking, marijuana use and tobacco smoking) in 2013–2015 and regressed BMI onto these classes (in repeated cross-sectional analyses) in youth in Ontario, Canada, participating in COMPASS. The authors found that latent classes with inactivity and substance use in females were associated with higher odds of overweight/obesity relative to active and non-substance-using females; in contrast, activity and experimenting with substance use in males were associated with higher odds of overweight/obesity relative to inactive non-substance-using males.[17]

However, whether individuals in these latent classes had higher BMIs, for both sexes/genders, relative to their counterparts at follow-up remains unknown. This information is crucial for obesity and substance use prevention programs because CDRB are modifiable, and addressing them while youth are at school can help mitigate the impact of factors associated with high/increasing BMI. As such, the aim of this study was to investigate the prospective association of CDRB latent classes, namely physical inactivity, binge drinking, marijuana use and tobacco smoking, with BMI, while accounting for gender, among participants in COMPASS in Ontario, Canada.

Methods

COMPASS is a large longitudinal study (2012–2021) collecting behaviour and outcome data from secondary school students in Canada. Further information on COMPASS (http://www.compass.uwaterloo.ca) is available elsewhere.[21]

This study used three waves of COMPASS data from Ontario, Canada. Wave 1 was collected in the 2013/14 school year, Wave 2 in the 2014/15 school year and Wave 3 in the 2015/16 school year. Consistent with earlier research,[6,17] we chose to focus our attention on Ontario data as these constitute 92% of the observations for these waves of COMPASS data.

Participants

A total of 41 734 youth in Grades 9, 10, 11 or 12 responded to the student questionnaire in Wave 1, 39 013 responded in Wave 2 and 37 106 responded in Wave 3. Most of the students who did not respond (20.9%, 21.6% and 20.1% in Waves 1, 2 and 3, respectively) were absent from school the day the questionnaire was administered. Students were recruited from schools that permit active-information, passive-consent protocols (n = 79, 78 and 72 in Waves 1, 2 and 3, respectively). In addition to the approval of the schools and school boards, the University of Waterloo Office of Research Ethics approved all procedures. Passive consent was obtained from participants.

Schools that participated in at least two of the three waves (n = 70 in each wave) were included in this study. Youth who responded to the student questionnaire more than once (n = 6594) were included in the study.

Measures

Body mass index (dependent variable)

We calculated BMI from the self-reported height and weight measures. We used the World Health Organization sex-specific BMI-for-age cut-off values corresponding to the age of our sample.[22] The measures used to determine BMI in COMPASS participants have previously been validated (intraclass correlation coefficient [ICC] = 0.84).[23]

BMI calculated at each time-point ranged from 10.0 to 49.9 kg/m^2, which suggests the presence of outliers. On removal of outliers at the 1% and 99% ends of the range, BMI was 15.5 to 35.9. BMI was used as a continuous and as a binary outcome (weight status) for comparative purposes. We used weight status based on BMI cut-offs (overweight/obese versus normal weight) because youth classified as overweight or obese have similar risks of future chronic diseases[24]; in addition, doing so is consistent with previously published studies.[15,17,25]

Chronic disease risk behaviours (independent variables)

The CDRB measures and multilevel latent class analysis procedure are briefly described below. (For more information, see Hammami et al.[17])

Physical activity

We described youth as being physically active if they were in compliance with the *Canadian 24-Hour Movement Guidelines for Children and Youth*.[17,26]

Substance use behaviours

To identify current cigarette smokers, the questionnaire included questions asking (1) if respondents had ever smoked 100 or more whole cigarettes in their life; and (2) on how many days respondents had smoked one or more cigarettes in the past 30 days. Students who answered "yes" to the first question, and reported any smoking in the previous 30 days were identified as current smokers.[17,27]

To identify binge-drinking behaviour, respondents were asked how often they had had five or more drinks of alcohol on one occasion during the past 12 months. Current binge drinkers were identified as those who had had five or more drinks at least once in the last month.[17,28,29]

Respondents were asked how often they used marijuana or cannabis during the past 12 months. They were classified as current marijuana users if they had used marijuana in the last month.[17,28,29]

Chronic disease risk behaviour (CDRB) latent classes

We previously conducted multilevel latent class analysis using gender-specific models for Waves 1–3 of the data in this study to independently assess the consistency of the CDRB profiles identified over time.[17] The findings suggested either two latent classes, active experimenters and inactive non-users, or three latent classes, active experimenters, inactive non-users and inactive substance users.

To ensure that the classes studied over time (in terms of their association with

BMI) were comparable, we assumed that the classes were fixed in number and type.[30] Since all waves in our study had at least two latent classes, we performed our longitudinal analyses with a parsimonious model of two student latent classes; in addition, this parsimony makes for easier interpretation and communication of findings.

Other variables: ethnicity and gender

We identified ethnicity based on responses to the question "How would you describe yourself?" in the student questionnaire. Options for answers were "White," "Black," "Asian," "Aboriginal (First Nations, Métis, Inuit)," "Latin American/Hispanic" or "Other." We grouped all the non-White ethnicities as they constituted only about 25% of the sample. In these analyses ethnicity is only used as a control variable.

We identified gender based on the answer to the question "Are you female or male?" with the options "female" and "male" as answers.

Statistical analyses

For variable descriptive statistics, we calculated gender-specific frequencies and percentages for categorical variables of interest and reported means and standard deviations for continuous variables. All analyses in this study used statistical package SAS version 9.4 (SAS Institute Inc., Cary, NC, USA) with a threshold of significance $p < .05$.

Bivariate exploratory analysis was conducted using McNemar test to assess the degree to which youth changed weight status categories and latent classes (i.e. transitions) across consecutive waves.

We used gender-stratified mixed-effects regression models to assess the longitudinal association between (lagged) CDRB latent classes and BMI (at follow-up). These models considered the outcome BMI in two ways: as continuous BMI and as binary BMI (overweight/obese versus normal weight). All mixed models adjusted for the following predictors while accounting for the hierarchical structure of the data: BMI (in the previous wave), ethnicity (at baseline), grade (at current wave) and year.

All mixed-effects regression models restricted analysis to monotone patterns of missingness in the outcome variable via maximum likelihood, based on the assumption that the data are "missing at random."[31] Altogether 4510 youth participated in at least two student questionnaires across the three waves (with a monotone pattern of missing BMI) and were included in the analyses.

Results

Study participants

For each of the three Waves, females accounted for 51.1% of secondary school students responding (Table 1). The mean BMI at Wave 1 was 21.0 in females and 21.6 in males (classified as normal weight). Estimates were similar at Waves 2 (females, 21.6; males, 22.4) and 3 (females, 21.9; males, 22.9).

More than half of the female youth reported a normal BMI (55.2%, 55.0% and 55.2% for Waves 1, 2 and 3, respectively). This was higher than the proportion of males reporting a normal BMI (44.8%, 45.0% and 44.8%, respectively). In tandem, males reported higher overweight/obesity rates (61.7%, 61.1% and 61.5%, respectively) than their female

TABLE 1
Summary statistics for longitudinal outcomes and covariates, by gender, Grade 9–12 secondary school students, COMPASS (Ontario, Canada)

Demographics	Study participants, % (n)[a]					
	Wave 1		Wave 2		Wave 3	
	Females	Males	Females	Males	Females	Males
Gender distribution	51.1 (2307)	48.9 (2203)	51.1 (2307)	48.9 (2203)	51.1 (2307)	48.9 (2203)
Ethnicity						
White	51.5 (1826)	48.5 (1721)	–	–	–	–
Non-White	50.2 (474)	49.8 (470)	–	–	–	–
Grade						
9	50.7 (1551)	49.3 (1505)	–	–	–	–
10	53.0 (724)	47.0 (643)	50.7 (1541)	49.3 (1500)	–	–
11	36.8 (32)	63.2 (55)	53.1 (728)	46.9 (643)	50.7 (1532)	49.3 (1488)
12	–	–	37.4 (31)	62.6 (52)	52.3 (747)	47.7 (682)
Weight status (binary BMI)[b]						
Normal	55.2 (1896)	44.8 (1541)	55.0 (1782)	45.0 (1457)	55.2 (1642)	44.8 (1334)
Overweight/obese	38.3 (411)	61.7 (662)	39.9 (413)	61.1 (648)	38.5 (362)	61.5 (578)
Continuous BMI (SD)	21.0 (3.1)	21.6 (3.4)	21.6 (3.2)	22.4 (3.5)	21.9 (3.2)	22.9 (3.5)
Latent classes						
Active experimenters	59.0 (128)	41.0 (89)	49.9 (253)	50.1 (254)	46.0 (354)	54.0 (415)
Inactive non-users	50.8 (2179)	49.2 (2114)	51.3 (2054)	48.7 (1949)	52.2 (1953)	47.8 (1788)

Abbreviations: BMI, body mass index; COMPASS, Cohort Study on Obesity, Marijuana Use, Physical Activity, Alcohol Use, Smoking and Sedentary Behaviour; SD, standard deviation.

[a] Percentages and sample size are reported for categorical variables; mean and standard deviation are reported for continuous variables.

[b] BMI weight status categorizations were age- and sex-specific as reported from the World Health Organization (WHO) growth charts.[22]

counterparts (38.3%, 39.9% and 38.5%, respectively).

Weight status transitions

Most youth who were classified as having a normal weight remained in this category at follow-up (Wave 1 to 2: females = 92.8%, males = 89.5%; Wave 2 to 3: females = 95.0%, males = 90.3%) (Table 2). Youth with overweight/obesity also tended to remain in the same category across consecutive waves (Wave 1 to 2: females = 75.1%, males = 78.4%; Wave 2 to 3: females = 78.4%, males = 77.7%).

A lower proportion of females than of males reported transitioning from a normal weight to overweight/obesity at follow-up (Wave 1 to 2: females = 7.2%, males = 10.5%; Wave 2 to 3: females = 5.0%, males = 9.7%). A greater proportion of female youth transitioned from overweight/obesity to normal weight at follow-up (Wave 1 to 2: females = 24.9%, males = 21.6%; Wave 2 to 3: females = 21.6%, males = 22.3%). These transitions were found to be significant only in females for Wave 1 to 2.

Latent class transitions

Most active experimenters were the same at follow-up (Waves 1 to 2: females = 71.9%, males = 71.9%; Waves 2 to 3: females = 70.7%, males = 70.9%) (Table 3). Similarly, inactive non-users remained largely non-using at follow-up (Waves 1 to 2: females = 92.6%, males = 91.0%; Waves 2 to 3: females = 91.5%, males = 87.9%).

Transition from active experimenting to inactive non-user status occurred at higher rates than the reverse, that is, from inactive non-using to active experimenting status (Wave 1 to 2: females = 28.1%, males = 28.1%; Waves 2 to 3: females = 29.3%, males = 29.1%). A significant McNemar chi-square test statistic ($p < .0001$) suggests that there are statistically significant transitions in youth's CDRB latent classes across a 1-year period.

Longitudinal regression analyses

Male inactive non-users in the previous wave were associated with an average increase of 0.29 in continuous BMI at follow-up relative to their active experimenter counterparts (95% confidence interval [CI]: 0.057, 0.53) (Table 4). When weight status was used as an outcome, inactive non-using males were associated with 72% higher odds of overweight/obesity relative to their active experimenter counterparts (OR = 1.72, 95% CI: 1.2, 2.4). No significant associations were identified in females.

TABLE 2
Transitions in weight status across consecutives waves (Waves 1 to 2 and 2 to 3), by gender, Grade 9–12 secondary school students, COMPASS (Ontario, Canada)

	Population	Binary BMI status[a], % (n) Normal	Overweight/obese	McNemar chi-square
		Wave 2		
Wave 1	**Females**			
	Normal	92.8 (1688)	7.2 (130)	5.78*
	Overweight/ Obese	24.9 (94)	75.1 (283)	
	Males			
	Normal	89.5 (1321)	10.5 (155)	1.24
	Overweight/ Obese	21.6 (136)	78.4 (493)	
		Wave 3		
Wave 2	**Females**			
	Normal	95.0 (1565)	5.0 (82)	0.16
	Overweight/ Obese	21.6 (77)	78.4 (280)	
	Males			
	Normal	90.3 (1205)	9.7 (129)	0
	Overweight/ Obese	22.3 (129)	77.7 (449)	

Abbreviations: BMI, body mass index; COMPASS, Cohort Study on Obesity, Marijuana Use, Physical Activity, Alcohol Use, Smoking and Sedentary Behaviour.

[a] BMI weight status categorizations were age- and sex-specific as reported from the World Health Organization (WHO) growth charts.[22]

* $p < .05$.

Discussion

Building on earlier research,[17] we conducted a longitudinal analysis assessing for gender differences in the association of CDRB with BMI at follow-up. Our assessment shows that, at follow-up, BMI was higher by 0.29 in inactive non-using males than among active experimenters, with no such significant association in females. In addition, inactive non-using males were associated with 72% higher odds of overweight/obesity relative to their more active counterparts who experiment with substances.

Our findings emphasize the importance of stratified analyses that assess the association between CDRB and longitudinal BMI because the results of cross-sectional analyses in our earlier research[17] are not likely to be consistent with findings from longitudinal analyses.

Substance use is associated with higher prevalence and incidence of obesity.[12,14,19,32] Our findings can be partially explained by the difference in physical activity across the two classes. Physical activity was found to be protective against obesity in male but not female youth in the United States.[33]

Physical activity is not the sole behaviour that contributes to differences in overweight/obesity. Research shows that unhealthy CDRB collectively contribute to higher BMI in youth. Low physical activity does not occur in isolation; it is usually associated with poor dietary intake and sedentary behaviour, and how research is conducted should reflect that.[34-37]

The problem behaviour theory (1977) explains that youth who engage in one problem behaviour are at a higher risk of other problem behaviours due to the shared meanings and the social influences surrounding the behaviours.[38] Research indicates that behaviour change (positive or negative) is more effective when the behaviours are addressed simultaneously rather than each in isolation.[39] Furthermore, peer effects are reportedly associated with differences in diet, exercise and BMI.[37,40] Recent findings from Europe also suggest that active experimenters likely have experimenter friends who tend to be

TABLE 3
Transitions in latent classes across consecutive waves (Waves 1 to 2 and 2 to 3), by gender, Grade 9–12 secondary school students, COMPASS (Ontario, Canada)

		Chronic disease risk behaviour latent classes, % (n)		McNemar chi-square
		Active experimenters	Inactive non-users	
		Wave 2		
Wave 1	Females			
	Active experimenters	71.9 (92)	28.1 (36)	79.3***
	Inactive non-users	7.4 (161)	92.6 (2018)	
	Males			
	Active experimenters	71.9 (64)	28.1 (25)	126.6***
	Inactive non-users	9.0 (190)	91.0 (1924)	
		Wave 3		
Wave 2	Females			
	Active experimenters	70.7 (179)	29.3 (74)	41.0***
	Inactive non-users	8.5 (175)	91.5 (1879)	
	Males			
	Active experimenters	70.9 (180)	29.1 (74)	83.9***
	Inactive non-users	12.1 (235)	87.9 (1714)	

Abbreviation: COMPASS, Cohort Study on Obesity, Marijuana Use, Physical Activity, Alcohol Use, Smoking and Sedentary Behaviour.
***p <.0001.

physically active in their free time. It is reported that athletes' perceived social norms and increased exposure to alcohol through alcohol advertising during sporting events play a prominent role in their higher drinking habits relative to their peers.[41,42] Similarly, inactive non-using youth likely have non-using friends with sedentary pastimes (e.g. TV viewing, video games).[37]

Consistent with earlier research,[5,6] our analyses indicate that there are annual increases in BMI across genders but that the predictors of the annual increase differ. Physical activity and substance use are not likely predictors of increasing BMI in females. Studies show that adult women have healthier dietary patterns than adult men.[43] Nevertheless, a study of adults in Scotland, England and Northern Ireland reported that variance in BMI was explained by physical activity (by 10.3%) and dieting behaviours (by 10.3%), while healthy eating explained only 1.6% of the variance.[43]

TABLE 4
Adjusted estimates from mixed-effects models[a] that regressed BMI onto lagged latent classes, by gender, Grade 9–12 secondary school students, COMPASS (Ontario, Canada)

Latent class in previous wave	Regression coefficients (95% CI)[b]	OR (95% CI)[c]
Females		
	Model 1	Model 2
Active experimenter (Ref.)		
Inactive non-user	−0.0087 (−0.20, 0.19)	0.85 (0.55, 1.32)
Males		
	Model 3	Model 4
Active experimenter (Ref.)		
Inactive non-user	0.29* (0.057, 0.53)	1.72** (1.2, 2.4)

Abbreviations: BMI, body mass index; CI, confidence interval; COMPASS, Cohort Study on Obesity, Marijuana Use, Physical Activity, Alcohol Use, Smoking and Sedentary Behaviour; OR, odds ratio; Ref.: reference.
[a] All models adjusted for BMI (in the previous wave), ethnicity (at follow-up), grade (at follow-up) and year.
[b] Regression coefficient (95% CI) from the linear regression, with continuous BMI as an outcome.
[c] Odds ratio from logistic regression, with normal weight as the reference category with binary BMI as the outcome.
*p < .05.
**p < .01.

We found that about one-quarter of youth transition to a "healthier" weight: 28.1% of youth with overweight/obesity in Wave 1 transitioned to a normal weight in Wave 2 and 27.3% of youth with overweight/obesity in Wave 2 transitioned to a normal weight in Wave 3. Similar findings were reported from Spain, where 26% of youth classified as obese transitioned to overweight status.[4] Over one-quarter of youth transitioning to a lower BMI category indicates the need for future research into attitudes, behaviours and peer and school effects in these youth. This will provide valuable lessons as to how youth successfully achieve a healthier weight.

BMI also tends to increase in adults, and there are fewer reported decreases than in youth. Over a span of 18 years, BMI in adults in the USA increased by 13% (equivalent to 3.1), with only 1.9% of women and 0.5% of men having a 1 unit decrease in BMI.[5] Our and others' findings[4] that a proportion of youth with overweight/obesity tend to transition to lower BMI categories emphasizes the importance of healthy weight loss and maintenance during adolescence.

From the point of obesity and chronic disease prevention, school-based interventions are warranted as they also associated with decreases in substance use.[44,45] Participatory approach programs, which are gaining popularity because of their success, encourage youth to participate and have succeeded at retaining students[46] as well as leading to decreases in BMI.[47] A meta-analysis shows that problem-solving training and techniques from cognitive behavioural therapy were beneficial, as were programs based on a social influences approach that teaches refusal skills.[48]

Tailored prevention and intervention programs (such as gender-specific programs) are reportedly more effective than those intended for the general population of youth.[49] Our findings are important because they show that youth have gender-specific longitudinal predictors of BMI, warranting targeted gender-specific prevention and intervention efforts. We recommend gearing school-based interventions for inactivity and substance use that promote healthy food intake specifically towards male students and unhealthy dieting behaviours specifically towards female students. The scientific literature supports that addressing more than one health behaviour simultaneously is associated with more desired intervention-outcomes especially when a recommendation for increasing physical activity or limiting screen time predominates.[50,51]

Strengths and limitations

Our study contributes to the discussion that CDRB are associated with youth health differently over time and between the genders. Our study adopted a novel approach by taking into consideration the dependence of students in schools in both the gender-specific multilevel latent class analysis and the gender-specific multilevel longitudinal regression analyses. Our findings suggest that increases in BMI at follow-up were significantly associated with the latent class, inactive non-using youth in males; there were no such associations in females. Similar studies that only adjusted for gender might have not found any association because they did not stratify by gender.[6] In addition, we accounted for monotone type missingness by using maximum likelihood models, based on the assumption that data are missing at random. These models are preferable over those that are based on complete case analysis because the latter assume the outcome is missing entirely at random.[31]

In terms of limitations, the student questionnaire is entirely self-reported and therefore subject to social desirability bias. However, previous analyses have shown that there are no significant differences in the prevalence of BMI in COMPASS self-reports versus those measured by a trained professional across a national sample of youth in Canada.[17] COMPASS participants' self-reported BMI have a high validity compared with measurements made by a trained professional (ICC = 0.84).[23]

In addition, the use of passive consent likely mitigates social desirability bias. Active consent procedures are discouraged when measuring substance use to avoid limiting the participation of substance users who are most likely to benefit from these programs.[52]

Only two latent classes were used in the analysis: active experimenters and inactive non-using youth. This does not mean that other youth were left out of the analyses; rather, it indicates that some youth may have had a better fit with another latent class, for example, inactive substance user.[17] To conduct our longitudinal analysis, the classes had to be fixed in this manner across the 3 years so that comparisons could be made over time.

Lastly, COMPASS is not generalizable to youth across Canada since it uses purposeful sampling. However, the prevalence of substance use and of BMI was comparable to those found in a nationally representative sample.[53]

Conclusion

Although previous cross-sectional analyses show that youth in latent classes with substance use are associated with higher BMI and higher odds of overweight/obesity,[17] our longitudinal findings indicate that inactive male youth who do not use substances are at 72% higher odds of overweight/obesity than their active peers who experiment with substance use. This indicates that physical activity plays a longitudinal role in male youth BMI. No longitudinal predictors of increase in BMI were identified in female youth when considering latent classes of physical activity and current substance use.

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Conflicts of interest

The authors have no conflicts to report.

Authors' contributions and statement

NH conceived this study and its design, conducted the analysis and drafted the manuscript as part of her PhD dissertation at the University of Waterloo.

AC supervised NH in the drafting of the manuscript, co-designed the analyses, interpreted the results and edited the manuscript's content.

STL conceived the COMPASS study and wrote the funding proposal, developed its tools and is leading its implementation and coordination.

AC, STL and PB provided ideas and thoughts for discussion.

All authors supported NH in the development of the study design, revision of earlier manuscript drafts and approved the final manuscript.

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References

1. Rodd C, Sharma AK. Recent trends in the prevalence of overweight and obesity among Canadian children. CMAJ. 2016;188(13):E313-20. doi: 10.1503/cmaj.150854.

2. Lloyd LJ, Langley-Evans SC, McMullen S. Childhood obesity and risk of the adult metabolic syndrome: a systematic review. Int J Obes. 2012;36(1):1-11. doi:10.1038/ijo.2011.186.

3. Simmonds M, Llewellyn A, Owen CG, Woolacott N. Predicting adult obesity from childhood obesity: a systematic review and meta-analysis. Obes Rev. 2016;17(2):95-107. doi:10.1111/obr.12334.

4. Devis-Devis J, Lizandra J, Valencia-Peris A, Pérez-Gimeno E, Garcia-Massò X, Peiro-Velert C. Longitudinal changes in physical activity, sedentary behavior and body mass index in adolescence: migrations towards different weight cluster. PLoS One. 2017;12(6): e0179502. doi:10.1371/journal.pone.0179502.

5. Malhotra R, Østbye T, Riley CM, Finkelstein EA. Young adult weight trajectories through midlife by body mass category. Obesity (Silver Spring). 2013;21(9):1923-34. doi:10.1002/oby.20318.

6. Laxer RE, Cooke M, Dubin JA, Brownson RC, Chaurasia A, Leatherdale ST. Behavioural patterns only predict concurrent BMI status and not BMI trajectories in a sample of youth in Ontario, Canada. PLoS One. 2018; 13(1):e0190405. doi:10.1371/journal.pone.0190405.

7. Spring B, Moller AC, Coons MJ. Multiple health behaviours: overview and implications. J Public Health (Oxf). 2012;34 Suppl 1:i3-10. doi:10.1093/pubmed/fdr111.

8. Battista K, Leatherdale ST. Estimating how extra calories from alcohol consumption are likely an overlooked contributor to youth obesity. Health Promot Chronic Dis Prev Canada. 2017;37(6):194-200. doi:10.24095/hpcdp.37.6.03.

9. Jackson SL, Cunningham SA. The stability of children's weight status over time, and the role of television, physical activity, and diet. Prev Med. 2017;100:229-34. doi:10.1016/j.ypmed.2017.04.026.

10. Jackson SL, Cunningham SA. Social competence and obesity in elementary school. Am J Public Health. 2015; 105(1):153-8. doi:10.2105/AJPH.2014.302208.

11. Lanza HI, Pittman P, Batshoun J. Obesity and cigarette smoking: Extending the link to E-cigarette/vaping use. Am J Health Behav. 2017;41(3):338-47. doi:10.5993/AJHB.41.3.13.

12. Delk J, Creamer MR, Perry CL, Harrell MB. Weight status and cigarette and electronic cigarette use in adolescents. Am J Prev Med. 2018;54(1):e31-5. doi:10.1016/j.amepre.2017.09.007.

13. Zeller MH, Reiter-Purtill J, Peugh JL, Wu Y, Becnel JN. Youth whose weight exceeds healthy guidelines are high-risk targets for tobacco prevention messaging and close monitoring of cigarette use. Child Obes. 2015;11(4):406-14. doi:10.1089/chi.2014.0113.

14. Pasch KE, Velazquez CE, Cance JD, Moe SG, Lytle LA. Youth substance use and body composition: does risk in one area predict risk in the other? J Youth Adolesc. 2012;41(1):14-26. doi:10.1007/s10964-011-9706-y.

15. Laxer RE, Brownson RC, Dubin JA, Cooke M, Chaurasia A, Leatherdale ST. Clustering of risk-related modifiable behaviours and their association with overweight and obesity among a large sample of youth in the COMPASS study. BMC Public Health. 2017;17(1):102. doi:10.1186/s12889-017-4034-0.

16. Arbour-Nicitopoulos KP, Faulkner GE, Leatherdale ST. Learning from non-reported data: interpreting missing body mass index values in young children. Meas Phys Educ Exerc Sci. 2010;14(4):241-51. doi:10.1080/1091367X.2010.520243.

17. Hammami N, Chaurasia A, Bigelow P, Leatherdale ST. A gender-stratified, multilevel latent class assessment of chronic disease risk behaviours' association with BMI among youth in the COMPASS study. Prev Med. 2019; 126(C):105758. doi:10.1016/j.ypmed.2019.105758.

18. Harvey A, Faulkner G, Giangregorio L, Leatherdale ST. An examination of school- and student-level characteristics associated with the likelihood of students' meeting the Canadian physical activity guidelines in the COMPASS study. Can J Public Health. 2017;108(4):e348-54. doi:10.17269/CJPH.108.5925.

19. Huang DY, Lanza HI, Anglin MD. Association between adolescent substance use and obesity in young adulthood: a group-based dual trajectory analysis. Addict Behav. 2013;38(11):2653-60. doi:10.1016/j.addbeh.2013.06.024.

20. Poitras VJ, Gray CE, Borghese MM, et al. Systematic review of the relationships between objectively measured physical activity and health indicators in school-aged children and youth. Appl Physiol Nutr Metab. 2016;41(6):S197-239. doi:10.1139/apnm-2015-0663.

21. Leatherdale ST, Brown KS, Carson V, et al. The COMPASS study: a longitudinal hierarchical research platform for evaluating natural experiments related to changes in school-level programs, policies and built environment resources. BMC Public Health. 2014; 14(1):331. doi:10.1186/1471-2458-14-331.

22. World Health Organization. Growth reference 5-19 years: BMI-for-age (5-19 years) [Internet]. Geneva (CH): World Health Organization; 2007 [cited 2019 Mar 8]. Available from: http://www.who.int/growthref/who2007_bmi_for_age/en/

23. Leatherdale ST, Laxer RE. Reliability and validity of the weight status and dietary intake measures in the COMPASS questionnaire: are the self-reported measures of body mass index (BMI) and Canada's food guide servings robust? Int J Behav Nutr Phys Act. 2013;10(1):42. doi:10.1186/1479-5868-10-42.

24. Peirson L, Fitzpatrick-Lewis D, Morrison K, et al. Prevention of overweight and obesity in children and youth: a systematic review and meta-analysis. CMAJ Open. 2015;3(1):E23-33. doi:10.9778/cmajo.20140053.

25. Carson V, Faulkner G, Sabiston C, Tremblay M, Leatherdale ST. Patterns of movement behaviors and their association with overweight and obesity in youth. Int J Public Health. 2015;60(5):551-9. doi:10.1007/s00038-015-0685-8.

26. Tremblay MS, Carson V, Chaput J-P, et al. Canadian 24-hour movement guidelines for children and youth: an integration of physical activity, sedentary behaviour, and sleep. Appl Physiol Nutr Metab. 2016;41(6 Suppl 3):S311-27. doi:10.1139/apnm-2016-0151.

27. Wong SL, Shields M, Leatherdale S, Malaison E, Hammond D. Assessment of validity of self-reported smoking status. Health Rep. 2012;23(1):47-53.

28. Leatherdale ST. An examination of the co-occurrence of modifiable risk factors associated with chronic disease among youth in the COMPASS study. Cancer Causes Control. 2015;26(4):519-28. doi:10.1007/s10552-015-0529-0.

29. Leatherdale ST, Burkhalter R. The substance use profile of Canadian youth: exploring the prevalence of alcohol, drug and tobacco use by gender and grade. Addict Behav. 2012;37(3):318-22. doi:10.1016/j.addbeh.2011.10.007.

30. Tomczyk S, Pedersen A, Hanewinkel R, Isensee B, Morgenstern M. Polysubstance use patterns and trajectories in vocational students—a latent transition analysis. Addict Behav. 2016;58:136-41. doi:10.1016/j.addbeh.2016.02.027.

31. Hedeker D, Gibbons RD. Longitudinal data analysis. Hoboken (NJ): John Wiley & Sons; 2006. 337 p.

32. Boone-Heinonen J, Gordon-Larsen P, Adair LS. Obesogenic clusters: multidimensional adolescent obesity-related behaviors in the U.S. Ann Behav Med. 2008;36(3):217-30. doi:10.1007/s12160-008-9074-3.

33. Govindan M, Gurm R, Mohan S, et al.; University of Michigan Health System. Gender differences in physiologic markers and health behaviors associated with childhood obesity. Pediatrics. 2013;132:468-74. doi:10.1542/peds.2012-2994.

34. Larson NI, Story M, Perry CL, Neumark-Sztainer D, Hannan PJ. Are diet and physical activity patterns related to cigarette smoking in adolescents? Findings from Project EAT. Prev Chronic Dis. 2007;4(3):A51.

35. Wilson DB, Smith BN, Speizer IS, et al. Differences in food intake and exercise by smoking status in adolescents. Prev Med. 2005;40(6):872-9. doi:10.1016/j.ypmed.2004.10.005.

36. Cureau FV, Sparrenberger K, Bloch KV, Ekelund U, Schaan BD. Associations of multiple unhealthy lifestyle behaviors with overweight/obesity and abdominal obesity among Brazilian adolescents: a country-wide survey. Nutr Metab Cardiovasc Dis. 2018; 28(7):765-74. doi:10.1016/j.numecd.2018.04.012.

37. Gwozdz W, Nie P, Sousa-Poza A, et al. Peer effects on weight status, dietary behaviour and physical activity among adolescents in Europe: findings from the I.Family Study. Kyklos. 2019;72(2):270-96. doi:10.1111/kykl.12197.

38. Jessor R, Jessor SL. Problem behavior and psychosocial development : a longitudinal study of youth. New York: Academic Press; 1977. pp. 289.

39. Geller K, Lippke S, Nigg CR. Future directions of multiple behavior change research. J Behav Med. 2017;40(1): 194-202. doi:10.1007/s10865-016-9809-8.

40. Chung SJ, Ersig AL, McCarthy AM. The influence of peers on diet and exercise among adolescents: a systematic review. J Pediatr Nurs. 2017; 36:44-56. doi:10.1016/j.pedn.2017.04.010.

41. Dams-O'Connor K, Martin JL, Martens MP. Social norms and alcohol consumption among intercollegiate athletes: the role of athlete and nonathlete reference groups. Addict Behav. 2007;32(11):2657-66. doi:10.1016/j. addbeh.2007.04.030.

42. Madden PA, Grube JW. The frequency and nature of alcohol and tobacco advertising in televised sports, 1990 through 1992. Am J Public Health. 1994;84(2):297-9. doi:10.2105/ajph.84.2.297.

43. Chambers JA, Swanson V. A health assessment tool for multiple risk factors for obesity: age and sex differences in the prediction of body mass index. Br J Nutr. 2010;104(2):298-307. doi:10.1017/S0007114510000607.

44. Simonton AJ, Young CC, Johnson KE. Physical activity interventions to decrease substance use in youth: a review of the literature. Subst Use Misuse. 2018;53(12):2052-68. doi:10.1080/10826084.2018.1452338.

45. Das JK, Salam RA, Arshad A, Finkelstein Y, Bhutta ZA. Interventions for adolescent substance abuse: an overview of systematic reviews. J Adolesc Health. 2016;59(4S):S61-75. doi:10.1016/j.jadohealth.2016.06.021.

46. Bogart LM, Cowgill BO, Elliott MN, et al. A randomized controlled trial of students for nutrition and eXercise: a community-based participatory research study. J Adolesc Health. 2014;55(3): 415-22. doi:10.1016/j.jadohealth.2014.03.003.

47. Heo M, Jimenez CC, Lim J, et al. Effective nationwide school-based participatory extramural program on adolescent body mass index, health knowledge and behaviors. BMC Pediatr. 2018;18(1):7. doi:10.1186/s12887-017-0975-9.

48. Onrust SA, Otten R, Lammers J, Smit F. School-based programmes to reduce and prevent substance use in different age groups: what works for whom? Systematic review and meta-regression analysis. Clin Psychol Rev. 2016;44:45-59. doi:10.1016/j.cpr.2015.11.002.

49. Simen-Kapeu A, Veugelers PJ. Should public health interventions aimed at reducing childhood overweight and obesity be gender-focused? BMC Public Health. 2010;10(1):340. doi:10.1186/1471-2458-10-340.

50. Yin HQ, Prochaska JO, Rossi JS, et al. Treatment-enhanced paired action contributes substantially to change across multiple health behaviors: secondary analyses of five randomized trials. Transl Behav Med. 2013;3(1):62-71. doi:10.1007/s13142-013-0193-4.

51. Albarracín D, Wilson K, Chan MS, Durantini M, Sanchez F. Action and inaction in multi-behaviour recommendations: a meta-analysis of lifestyle interventions. Health Psychol Rev. 2018;12(1):1-24. doi:10.1080/17437199.2017.1369140.

52. Thompson-Haile A, Bredin C, Leatherdale ST. Rationale for using active-information passive-consent permission protocol in COMPASS. Compass Technical Report Series. 2013;1(6). https://uwaterloo.ca/compass-system/sites/ca.compass-system/files/uploads/files/compass_tr_-_rational_for_passive_consent-_volume_1_issue_6.pdf

53. Leatherdale ST, Rynard V. A cross-sectional examination of modifiable risk factors for chronic disease among a nationally representative sample of youth: are Canadian students graduating high school with a failing grade for health? BMC Public Health. 2013;13(1):569. doi:10.1186/1471-2458-13-569.