Healthier diets to promote mental health in adolescents: building the evidence.

by

Julia Dabravolskaj

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

Doctor of Philosophy

in

Epidemiology

School of Public Health
University of Alberta

Abstract

Background: Unhealthy diet is a well-established risk factor for developing many physical health conditions in adolescents (e.g., obesity, type 2 diabetes). Evidence begins to emerge that unhealthy diet might also be implicated in the development of common mental disorders. While there is a plethora of high-quality prospective studies on the association between diet and mental disorders in adults, such studies in adolescents are scarce. The already high and rising burden of mental disorders in adolescents necessitates a careful examination of diet as a potential target for interventions to improve mental health in adolescents. The overarching goal of this dissertation was to estimate the effect of diet (alone and in combination with other lifestyle behaviours, including substance use behaviours) on mental health in Canadian middle adolescents (i.e., 14-17 years old).

Methods: The goal has been achieved in a series of four interconnected research papers that utilized data from the Cannabis, Obesity, Mental health, Physical activity, Alcohol, Smoking, and Sedentary behaviour (COMPASS) study – a large longitudinal study which annually collects survey data from ~60,000 grade 9 to 12 high school students in British Columbia, Alberta, and Ontario, and Secondary I-V students in Quebec.

Results: The systematic review in Chapter 2 revealed several methodological concerns in existing studies: i.e., inadequate adjustment for established confounders and unnecessary adjustment for intermediate variables, and the need for sensitivity and sex-based subgroup analyses. Studies identified in this evidence synthesis, along with those identified in another ongoing systematic review (PROSPERO CRD42021246478), informed a list of covariates that likely confound the diet-mental health association in adolescents: i.e., mental health at baseline, socio-economic status, age, eating behaviours, lifestyle behaviours (i.e., physical activity,

sedentary behaviours, sleep, and substance use behaviours, including tobacco smoking, vaping, cannabis and alcohol use), and social support. Analyses in a sample of 13,887 COMPASS study participants (Chapter 3) were adjusted for this set of confounders. Analyses revealed a small negative effect of sugar-sweetened beverages (SSB) consumption on depressive and anxiety symptoms, as well as a small positive effect of vegetables and fruit consumption on psychological wellbeing. In Chapter 4, the focus was on dietary trajectories in vegetables and fruit and SSB consumption in relation to depressive and anxiety symptoms in a prospective cohort panel of 5,653 COMPASS participants who provided their responses in three consecutive waves of data collection. Analyses showed that the consumption of VF and SSB changed for the worse over time, and that the rate at which these changes happen was associated with the severity of depressive symptoms (but not anxiety symptoms). Finally, in Chapter 5, a holistic approach was taken to account for the synergistic effect that a comprehensive range of co-occurring unhealthy lifestyle behaviours might have on mental health. Indeed, when considered in combination, meeting more recommendations was generally associated with lower severity of depressive and anxiety symptoms at one-year follow-up.

Conclusion: The results of this thesis highlight the need for dietary interventions (particularly those implemented at the policy level, such as taxation of SSBs, banning food marketing to children, and subsidizing healthy foods to low-income families, among others) as part of comprehensive population-level primary prevention strategies, which target other lifestyle behaviours as well, to improve mental health in adolescents.

Preface

This thesis is an original work by Julia Dabravolskaj, who came up with the research ideas for all four manuscripts included in this thesis. The research project, of which this thesis is a part, received research ethics approval from the University of Alberta Research Ethics Board, Project Name "Healthier diets to promote mental health in youth: building the evidence", No. Pro00119528, April 7, 2022, as well as "Investigating the role of adherence to multiple lifestyle recommendations for diet, physical activity, sedentary behaviour, sleep, smoking and cannabis use on preventing mental illness in a large prospective cohort of youth in the COMPASS study", No. Pro00103881, August 26, 2020.

Chapter 2 of this thesis has been published as: Dabravolskaj J, Marozoff S, Maximova K, Campbell S, Veugelers PJ. Relationship between fruit and vegetables intake and common mental disorders in youth: a systematic review. *Public Health Reviews*. 2022, 43:1604686. Alongside the mentorship of Drs. Maximova and Veugelers, Dabravolskaj was responsible for designing and conducting (with the help of Marozoff and Campbell) this systematic review and drafting and revising the manuscript.

Chapter 3 of this thesis is to be submitted to a peer-reviewed journal as: Dabravolskaj J, Patte KA, Yamamoto S, Leatherdale ST, Veugelers PJ, Maximova K. Investigating the association between diet and mental health outcomes in middle adolescence using the directed acyclic graph-informed regression modelling. Under the guidance of Drs. Maximova, Yamamoto, and Veugelers, Dabravolskaj conceptualized the study and methodology, developed the statistical plan, executed all analyses, interpreted the results, and drafted the manuscript. Dr. Leatherdale

conceived of the COMPASS study, developed the study tools, and is leading the implementation and coordination of the study, and – together with Dr. Patte – secured funding and resources for the ongoing COMPASS study. All authors read and approved the final manuscript.

Chapter 4 of this thesis is to be submitted to a peer-reviewed journal as: Dabravolskaj J, Yamamoto S, Patte KA, Leatherdale ST, Veugelers PJ, Maximova K. Temporal changes in the consumption of vegetables and fruit and sugar-sweetened beverages, and their impact on depression and anxiety among adolescents: A longitudinal analysis of COMPASS data. Under the supervision of Dr. Maximova, Dabravolskaj developed an analysis plan, executed all analyses, and drafted the manuscript. Drs. Veugelers, Patte, Yamamoto, and Leatherdale reviewed the original draft and provided suggestions for revisions. Dabravolskaj finalized the draft of the manuscript.

Chapter 5 of this thesis is currently under review in the International Journal of Behavioral Nutrition and Physical Activity as: Dabravolskaj J, Veugelers PJ, Amores A, Leatherdale ST, Patte KA, Maximova K. The impact of 12 modifiable lifestyle behaviours on depressive and anxiety symptoms in middle adolescence: prospective analyses of the Canadian longitudinal COMPASS study. Under the mentorship of Drs. Maximova and Veugelers, Dabravolskaj conceptualized the study and methodology and developed a statistical analysis plan. Drs. Veugelers and Maximova secured funding and resources for this specific project. Amores assisted with statistical analyses, and Dabravolskaj interpreted the results and drafted the manuscript. All authors read and approved the final manuscript.

Dedication

I dedicate this dissertation to my daughter, Eva. Your laughter brightens up the gloomiest of days.

Acknowledgments

As just about any thesis that has ever been written, this one would not have been possible without the continuous presence of very special people in my life: people I respect and admire, people who have been with me every step of the way. First and foremost, a heartfelt thank you to my mentors, Drs. Katerina Maximova and Paul J. Veugelers, for seeing the potential behind my GPA and accepting me as their student, and for their unwavering financial and emotional support. They have been by my side through thick and thin, and at times only their kindness and endless understanding of my life circumstances helped me keep going and get to where I am now. They taught me what it means to be a researcher with integrity and empathy, and I will make sure to pay it forward.

I would also like to thank Dr. Shelby Yamamoto, who introduced my peers and me to causal inference and novel epidemiological methods. Her and Dr. Sentil Senthilselvan's course truly deepened my understanding of epidemiology and where the discipline is heading. A big thank you to all COMPASS participants and Dr. Scott T. Leatherdale for granting access to their rich data gathered over the years. I would also like to thank Dr. John Paul Ekwaru for his support and patience while explaining multilevel modelling (happy to report, I finally got it!) and for the thought-provoking conversations about academia and life in general.

Finally, thank you to my family and closest friends. Thank you to my Mom and Dad, who have been the source of unconditional love and support throughout my life. I know that my journey away from home has not been easy on them, and my love and respect for them and their sacrifices have no boundaries. Thank you to my brother Vadim, who always picks up his phone

when life seems to get entirely off the rails. Thank you to my partner Dennis who encouraged me to enroll in a Ph.D. program; without his gentle nudge, I would be contemplating this idea until this day. Finally, thank you to my closest friends Polina and Eugene for decades of friendship and deep connection, to Dr. Marjan Abbasi for our 'laughing sessions,' and to Nesa for being my wonderful partner in motherhood these past few years.

I have also been honoured to receive financial support from Alberta Education and the University of Alberta (Alberta Graduate Excellence Scholarship), and the Institute of Health Economics (Mazankowski Bursary Award).

Table of Contents

List of Tables

List of Figures

List of Abbreviations

ABAKQ	Adolescent Behaviours, Attitudes, and Knowledge Questionnaire
AIC	Akaike's information criteria
ANOVA	Analysis of variance
CES-D	Center for Epidemiologic Studies Depression Scale
CESD-R-10	Center for Epidemiologic Studies Depression Scale Revised
CI	Confidence interval
CINAHL	Cumulative Index to Nursing and Allied Health Literature
CMD	Common mental disorder
COMPASS	Cannabis, Obesity, Mental health, Physical activity, Alcohol, Smoking, and Sedentary behaviour
COOPS/WONCA	Dartmouth COOP Functional Health Assessment charts/World Organization of Family Doctors
COVID-19	Coronavirus Disease 2019
DAG	Directed acyclic graph
EBSCO	Elton B. Stephens CO
ESC-DAG	Evidence synthesis for constructing directed acyclic graphs
FFQ	Food frequency questionnaire
FVI	Fruit and vegetables intake
GAD-7	Generalized Anxiety Disorder 7
GSHS	Global school-based Student Health Survey
IRR	Incidence rate ratio
JBI	Joanna Briggs Institute
K-BDI	Korean version of the Beck Depression Inventory
KYRBS	Korea Youth Risk Behaviour Web-based Survey
LL	Lower limit
LMM	Linear mixed-effects model
MeSH	Medical Subject Headings
MVPA	Moderate-to-vigorous physical activity
OR	Odds ratio
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PROSPERO	The International Prospective Register of Systematic Reviews
RCT	Randomized controlled trial
RR	Relative risk
SD	Standard deviation
SES	Socioeconomic status
SMFQ	Moods and Feelings Questionnaire – Short Form
SSB	Sugar-sweetened beverages
UK	United Kindgdom
UL	Upper limit
US	United Stated
VF	Vegetables and fruit
WOS	Web of Science
YRBS	Youth Risk Behaviour Survey

Chapter 1: Introduction

Mental health as an integral part of well-being

There is no health without mental health,[1] commonly defined as "a state of well-being in which every individual realizes her or his own potential, can cope with the normal stresses of life, can work productively and fruitfully, and is able to make a contribution to her or his own community".[2] Mental health is fundamental to our ability to think and act independently, receive life satisfaction and enjoyment, and build and maintain healthy family relations, friendships, and social interactions.[3] Not surprisingly, in a recent survey of 1,000 Canadians aged 18 years and older, 84% stated that the importance of mental health is no less than their physical health, and 12% believed its importance is even higher than that of physical health.[4]

A complex interplay of multiple biological, genetic, economic, and psychosocial risk factors—in the absence of sufficient protective factors—often undermines mental health, resulting in *mental health problems and illnesses*[1,5] (other terms commonly used are "mental health conditions" and – if diagnosed by a health professional – "mental disorders"[6]). Mental health conditions are defined as "the range of behaviours, thoughts and emotions that can result in some level of distress or impairment in areas such as school, work, social and family interactions and the ability to live independently."[7] One in five Canadians will experience a mental health condition in any given year, and by 40 years of age, every second person will have or have had at least one mental health condition.[8] Mental health conditions range from single episodes to chronic disorders, with sub-clinical manifestation being common.[9]

Apart from the psychosocial ramifications of living with mental health conditions (i.e., pain, distress, and the lack of the enjoyment of life), there are grave economic costs imposed by mental health conditions at the individual and societal levels. According to previously calculated estimates, mental health problems and illnesses cost Canadian taxpayers over $50 billion annually,[10] not to mention the economic costs incurred by informal caregivers, estimated to be $3.9 billion in lost income annually.[11] These estimates were projected to reach $88.8 billion in 2021: $79.9 and $8.9 billion in *direct* (associated with the treatment, support, and rehabilitation[11]) and *indirect* costs (associated with mental health-related disability claims, lost productivity due to absenteeism, i.e., staying away from work, and presenteeism, i.e., showing up at work while feeling ill, and social and judicial services[10]), respectively.[7] Although staggering, these estimates were calculated in early 2010s, well before the COVID-19 pandemic, and the actual costs of mental health conditions in 2021 undoubtedly surpassed the estimated costs by an order of magnitude.

Considering the burden of mental health conditions, one of the six strategic directions outlined in the seminal report by the Mental Health Commission of Canada *Changing directions, changing lives: the mental health strategy for Canada*,[1] is to "promote mental health across the lifespan in homes, schools, and workplaces, and prevent mental illness and suicide wherever possible" (p. 11). While the report underscores the importance of intervening across the lifespan, childhood and adolescence have been identified to be the period with the greatest potential for primary prevention of mental disorders and promotion of mental health and well-being.[12]

The burden of mental disorders in adolescents

The prevalence of mental health conditions in children and adolescents is around 15% worldwide,[13] but the prevalence is even higher in developed countries.[14] In Canada, around 20% of children and adolescents are living with at least one mental health condition.[15] Yet, while children (before age 10 years) and adolescents (10 – 19 years of age) are often considered together, there are important differences between these two age groups when it comes to mental disorders. Although some mental disorders (e.g., social and separation anxiety disorders) tend to appear in early childhood, the first symptoms of common mental disorders (i.e., anxiety, depression, attention deficit/hyperactivity and conduct disorders)[16] appear in adolescence in as many as 70% of cases.[14,17,18] For example, in a recent study that used diagnostic interviews to ascertain the prevalence of common mental disorders in a provincially-representative sample of 6,537 Ontario households, behavioural disorders (i.e., attention deficit/hyperactivity and conduct disorders) were more common in children (12% in children vs. 9% in adolescents). However, emotional disorders, which include anxiety (8% in adolescents vs. 1% in children) and depression (15% in adolescents vs. 9% in children), were more common in adolescents.[19]

As adolescents transition between early to late adolescence, the prevalence increases even more. For example, a nationally-representative face-to-face survey of 10,123 US adolescents aged 13–18, the lifetime prevalence of mood and anxiety disorders increased two- and three-fold, respectively, between the ages of 13-14 years and 17-18 years.[20] Moreover, the prevalence of common mental disorders is considerably higher in adolescent girls compared to boys. For example, compared to adolescent boys, a six-month prevalence of depressive disorder in adolescent girls was 10% (vs. 5% in adolescent boys) and of anxiety disorder 20% (vs. 10% in

adolescent boys).[19] These notable sex differences emerge early and are attributed to heightened stress sensitivity due to a shift in hormonal status,[21] and changes in brain morphology and structural and functional connectivity.[22]

There is evidence that despite being already high, the burden of mental disorders among adolescents continues to grow. Evidence from the Canadian Community Health Survey showed an increasing prevalence of self-reported mood disorder diagnoses between 2000 and 2014.[23] When data for 2015-2018 were included, the prevalence of self-reported mood and anxiety disorders diagnoses continued to increase: from 4% to 8% for mood disorders, and from 6% to 13% for anxiety disorders.[24] Consequently, the prevalence of mental health consultations also increased from 12% in 2011 to 17% in 2018,[24] and with it, a growing proportion of hospitalizations for mental disorders and a steady rise in the use of mood and anxiety medications (between 2016 and 2020), particularly among females.[25]

The burden of mental disorders in adolescents has been further accelerated by the COVID-19 pandemic that added many stressors that impacted their mental health and well-being (e.g., prolonged school closures, fear of contracting or having loved ones contract COVID-19, feelings of loneliness and hopelessness, the inability to seek comfort from extended family members and friends, among many others).[26] The pandemic also differentially affected adolescents, and those living in socioeconomically disadvantaged settings, with its many additional stressors (e.g., food insecurity, parental loss of jobs or income,[27] and disruptive family dynamics[28]), were hit harder.[29,30] While experts agree that, as of September 2022, the end of the COVID-19 pandemic "is in sight,"[31] evidence on its profound and lasting adverse impacts on mental health of

adolescents is unequivocal. For example, a recent meta-analysis of 29 studies showed the estimated global prevalence of elevated depression and anxiety symptoms in adolescents in the first year of the COVID-19 pandemic to be 21%.[32] These estimates are approximately double the pre-pandemic levels, with the prevalence being higher in female adolescents.

Adolescence is a sensitive period for later health outcomes,[33] including mental health outcomes. It is one of the most critical developmental periods that, in terms of the pace of changes occurring across multiple body systems, is second only to the fetal period and infancy.[33] It is precisely during adolescence that the brain undergoes major changes, with a rapid increase in white matter and a gradual decrease in grey matter.[34] During this period of protracted brain development, neural plasticity is particularly high, which comes at a cost of a brain's increased susceptibility to environmental influences (e.g., drug use, social stressors).[34] This could explain the age-of-onset and a high prevalence of mental disorders in adolescents.

Importantly, emerging adulthood (defined as 18–25 years old[35,36]) is yet another period of life marked by a number of important changes. While brain development is beginning to slow down,[33,34] there is a multitude of socio-related factors that come into play (e.g., increased exposure to risky health behaviours,[37–39] gaining autonomy, changing relationships with family members, pursuing further education or paid employment after graduation[40]). Therefore, the costs of *not* preventing new and managing existing mental disorders in adolescence are significantly compounded. Moreover, interventions are much harder to implement and maintain in young adults, compared to adolescents who still go to school – an ideal setting for health promotion and primary prevention of both physical and mental health conditions.

The effectiveness of existing treatment strategies in adolescence is limited

Early signs of mental disorders in adolescence are often missed or dismissed as expected changes in behaviour due to rapid brain development. Even if recognized as red flags, there still exist numerous barriers to accessing mental health services, which include limited mental health knowledge, perceived social stigma and embarrassment, issues with trusting an unknown person, financial costs, and the availability of mental health services, among other factors.[41] Moreover, even when adolescents do access mental health services early on, the management of existing disorders is challenging as available treatment strategies have limited effectiveness in adolescents[42] and are generally recommended for moderate to severe cases only.[43] Moreover, recurrence following remission is highly prevalent; for example, recurrence of depressive symptoms within five years occurs in as many as 70% of cases.[21] Finally, common mental disorders often co-occur with each other (e.g., depression commonly co-occurs with anxiety, attention deficit disorders, and conduct disorders[44]) and physical conditions (e.g., asthma, thyroid dysfunction, diabetes), with comorbidity becoming apparent early in the natural history.[45]

These challenges in diagnosing and managing mental disorders in children and adolescents, coupled with early age-of-onset, often result in a cascade of long-term negative psychosocial outcomes, such as functional and social impairment (e.g., low educational attainment, poor work performance,[46] difficulty developing stable relationships and social networks), socioeconomic consequences (e.g., unemployment and relational strain),[47] an increased risk of physical health issues (e.g., diabetes)[21,46] and future mental disorders,[48] substance abuse, and suicide.[21] Of course, these long-term consequences affect not only individuals living with mental disorders, but their families and society as a whole.[14] Given the high and ever-growing burden of mental

health conditions in adolescents, diagnostic- and treatment-related challenges, and the far-reaching negative consequences, it is imperative to develop and implement population-level prevention and promotion approaches to improve youth mental health.[49–51]

Primary prevention of mental health problems and illnesses is urgently needed

Primary prevention of mental health problems and illnesses aims to facilitate protective factors and avert or minimize risk factors.[52] Primary prevention that focuses on enhancing protective factors overlaps with health promotion, which is concerned with positive mental health and well-being and focuses on improving self-esteem, resilience to stress, and social skills, among other outcomes.[52] Primary prevention can be universal (targeting an entire group or a population, or population-level primary prevention), selective (targeting those at increased risk of mental disorders), and indicated (targeting those at a particularly high risk or those who are already exhibiting subclinical symptoms).[52,53] Although evidence shows that targeted prevention of mental disorders appears more effective and cost-effective than universal primary prevention,[54] the latter covers not only those at increased risk of mental disorders, but serves as a protective shield for *all* children and adolescents[55] and has been shown to reduce inequalities and be cost-effective as it targets multiple outcomes.[56]

Lifestyle behaviours are a potentially promising target for universal primary prevention of mental disorders, as most healthy and unhealthy lifestyle behaviours are first acquired and consolidated in adolescence, and then track into adulthood.[57–59] There is ample evidence of the preventive potential of some lifestyle behaviours, such as sleep,[60] physical activity,[61] substance use,[62] sedentary behaviour and social media use.[63] Recent evidence identifies unhealthy diet as a

potential prevention intervention target as well.[64–67] Given that an unhealthy diet accounts for the greatest share of the Global Burden of Disease,[64] improving diet may emerge as a novel and promising intervention strategy to reduce the burden of mental disorders in youth.[67,68] However, before we can recommend it for universal primary prevention of mental disorders in adolescents, it is crucial to emphasize that universal primary prevention is effective only if it targets a factor that – individually or in combination with other factors – causes a disease under study and if there is an effect of sufficient magnitude that this factor (or factors) produces.[69]

The study design that brings us as close to causal inference as possible is the randomized controlled trial (RCT) study, due to the expected lack of confounding bias.[70] Yet, despite the benefits of large long-term RCTs in the field of nutritional epidemiology and health promotion research in general,[71,72] this study design simply cannot answer the research questions at hand "Is diet causally related to mental health outcomes in adolescence?" and "How strong is the effect of diet on mental health outcomes in adolescence?", as succinctly summarized by Satija et al.[73,74] First, there are ethical concerns: it is unethical to randomize participants given our extensive knowledge of positive and negative effects of healthy and unhealthy diet, respectively, on multiple health outcomes. Thus, the principle of clinical equipoise is violated (i.e., there is no question about whether healthy diet is better than unhealthy – we already know the answer). The treatment assignment in an RCT of dietary interventions can never be fully blinded due to the nature of the intervention. Compliance is also problematic, particularly when longer follow-up is required (which is often the case when studying chronic physical and mental illnesses), which often results in high drop-out rates. The latter, in turn, can reduce the analytical power or, at its worst (i.e., when the dropout is differential in respect to the exposure and/or outcome), introduce

systematic bias of an unpredictable direction. Indeed, randomized treatment assignment balances covariates at baseline, thus ensuring that the treatment and control groups are exchangeable, however, given the aforementioned problems, these groups might not be as exchangeable post-baseline. Moreover, external validity is questionable: participants in both groups are often selected on the basis of their motivation and health consciousness.[75]

Considering these points and lacking a better "gold standard" (other than RCT) in the field of nutritional epidemiology (and epidemiology and clinical research in general[76]), the closest we can get to inferring causality is through carefully planned and conducted observational studies, and specifically prospective cohort studies. Compared to other observational study designs, prospective cohort design allows researchers to: minimize the impact of reverse causation (i.e., when the observed relationship is explained by the causal link between existing mental disorders and poorer diet); study mental health outcomes which may have long latency period with respect to diet; account for time-varying nature of variables; and have greater flexibility to collect additional information as needed, thus reducing (although not eliminating) the threat of residual confounding.[74]

Proposed mechanisms linking diet and mental disorders

Hypothesized biological mechanisms that could, in theory, link diet to mental health include beneficial effects of healthy diet on neurotransmitter systems, neuronal plasticity and proteins crucial for brain development in adolescence,[77] reduction of excessive oxidative stress[78] and low-grade inflammation,[79] and composition of gut microbiota that has been linked to behavioral problems in children.[80] These and other potential mechanisms or pathways have been

summarized in a recent narrative review by Marx et al.[81] The authors noted that there may be many more potential pathways which are complex, multifaceted, interacting, and not restricted to any one particular pathway. This work by Marx et al.[81] sparked an interesting discussion in the field of nutritional psychiatry.

A recent commentary by Molendijk et al.,[82] written in response to this narrative review by Marx et al.,[81] argues that there is no substantive evidence to prove that there is a link between diet and mental health. The authors pointed out that the "mechanisms of action" proposed by Marx et al. consist merely of associations between "diet → change in biomarkers" and "change in biomarker → depression onset/treatment effect." Molendijk et al. emphasized that future research exploring relationships between diet and neurobiology is needed, but as of now, there is not much to mediate. In support of this claim, the commentary also cites their team's recent publication: a systematic review, which included 24 narrative reviews, 12 systematic reviews and 14 meta-analyses that explored the effects of diet on depression in the general population.[83] In this systematic review, Thomas-Odenthal et al. concluded that in the field of nutritional psychiatry, oftentimes it is narrative reviews that come to stronger conclusions regarding the link between diet and mental health, despite inconclusive evidence. Indeed, narrative reviews were estimated to be nine times more likely to provide strong conclusions that diet is related to mental health outcomes, compared to systematic reviews or meta-analyses, even though they used almost 50% fewer studies to reach these conclusions. In turn, systematic reviews were more likely to report stronger conclusions than meta-analyses.

Knowledge gaps and research objectives of this thesis

The only two systematic reviews[67,68] addressing the relationship between diet and mental health outcomes in children and adolescents conclude that there seemed to be an association (generally of small magnitude) of unhealthy dietary patterns and low-quality diet with depression or poor mental health. However, the authors highlighted an array of valid methodological concerns in the available literature, including a limited number of prospective cohort studies and suboptimal adjustment for confounders. Moreover, there have been calls to utilize an array of sensitivity analyses to "[delineate] the magnitude of unmeasured confounding needed to completely neutralize an effect" in the field of nutritional epidemiology[74] and to acknowledge that no statistical models (however complex) exist independently of theories.[84] These concerns will be front and center in the current thesis and have shaped the approach that was taken to assess the relationship of diet with mental health outcomes in adolescents.

Ahead of data analyses, I invested considerable effort to create a causal model for the relationship between diet and mental health in adolescents. First, I immersed myself in the literature by conducting a systematic review of the relationship between diet and common mental disorders in adolescence (Chapter 2). This systematic review's main research objective was to summarize existing evidence on the diet-mental health relationship in adolescents, with a focus on methodological concerns. However, this systematic review serves a broader purpose: prospective cohort studies included in it informed a list of covariates that were used to create a causal model (or a directed acyclic graph [DAG]). This causal model informed data analyses presented in Chapters 3 and 4.

Specifically, Chapter 3 presents the results of causal model-informed regression analysis of the relationship between diet and a range of mental health outcomes (i.e., depressive and anxiety symptoms, psychological well-being) in a longitudinal Cannabis, Obesity, Mental health, Physical activity, Alcohol, Smoking, and Sedentary behaviour (COMPASS) study. In this chapter, I also present the results of several approaches to sensitivity analyses, including those estimating the strength of unmeasured confounders that could nullify the observed associations. In Chapter 4, I re-conceptualize the exposure of interest to account for diet being a dynamic exposure, and thus I report on regression analyses used to estimate the association between individual dietary trajectories and mental health outcomes in COMPASS study. Chapter 5 takes a more holistic approach to examine the effect of diet on mental health outcomes in adolescence in combination with other lifestyle behaviours (i.e., physical activity, screen time, sleep, use of tobacco, e-cigarettes, cannabis, and binge drinking). Finally, the Discussion section (Chapter 6) brings results from all four studies together and includes directions for future research and public health recommendations stemming from this dissertation.

References

1. Mental Health Commission of Canada. *Changing directions, changing lives: the mental health strategy for Canada*. Calgary: Mental Health Commission of Canada; 2012. https://central.bac-lac.gc.ca/.item?id=Strategy_Document&op=pdf&app=Library
2. World Health Organization. *Mental health: a state of well-being*. Geneva, Switzerland: World Health Organization; 2022. https://www.who.int/features/factfiles/mental_health/en/
3. World Health Organization. *Investing in mental health: evidence for action*. Geneva, Switzerland: World Health Organization; 2013. https://apps.who.int/iris/bitstream/handle/10665/87232/9789241564618_eng.pdf?sequence=1
4. Ipsos. *Public perspectives: 3rd annual Canadian mental health check-up*. 2017. https://www.ipsos.com/sites/default/files/2017-08/IpsosPA_PublicPerspectives_CA_April%202017%20Mental%20Health.pdf
5. Mental Health Commission of Canada. *Toward recovery and well-being: a framework for a mental health strategy for Canada*. Mental Health Commission of Canada; 2009. https://www.mentalhealthcommission.ca/wp-content/uploads/drupal/FNIM_Toward_Recovery_and_Well_Being_ENG_0_1.pdf
6. World Health Organization. *Mental disorders*. Geneva, Switzerland: World Health Organization; 2022. https://www.who.int/news-room/fact-sheets/detail/mental-disorders
7. Mental Health Commission of Canada. *Making the case for investing in mental health in Canada*. Mental Health Commission of Canada; 2016. https://www.mentalhealthcommission.ca/sites/default/files/2016-06/Investing_in_Mental_Health_FINAL_Version_ENG.pdf
8. Canadian Mental Health Association. *Fast facts about mental health and mental illness*. Canadian Mental Health Association; 2021. https://cmha.ca/brochure/fast-facts-about-mental-illness/
9. Public Health Agency of Canada. *Report from the Canadian Chronic Disease Surveillance System: mental illness in Canada.* 2015. https://www.canada.ca/en/public-health/services/publications/diseases-conditions/report-canadian-chronic-disease-surveillance-system-mental-illness-canada-2015.html#s1a
10. Lim KL, Jacobs P, Ohinmaa A, Schopflocher D, Dewa CS. A new population-based measure of the economic burden of mental illness in Canada. *Chronic Dis Can.* 2008;28(3):92–8.
11. Deraspe R. *Current issues in mental health in Canada: the economic impact of mental illness (in brief).* Library of Parliament, Ottawa, Canada; 2013. https://publications.gc.ca/collections/collection_2018/bdp-lop/eb/YM32-5-2013-87-eng.pdf
12. Jacka FN, Mykletun A, Berk M. Moving towards a population health approach to the primary prevention of common mental disorders. *BMC Med*. 2012;10(1):149.
13. Polanczyk GV, Salum GA, Sugaya LS, Caye A, Rohde LA. Annual research review: a meta-analysis of the worldwide prevalence of mental disorders in children and adolescents. *J Child Psychol Psychiatry*. 2015;56(3):345–65.
14. Kessler RC, Bromet EJ. The epidemiology of depression across cultures. *Annu Rev Public Health*. 2013;34:119–38.
15. Smetanin P, Stiff D, Briante C, Adair CE, Ahmad S, Khan M. *The life and economic impact of major mental illnesses in Canada.* Toronto, ON: RiskAnalytica, on behalf of

the Mental Health Commission of Canada; 2011. https://www.mentalhealthcommission.ca/sites/default/files/MHCC_Report_Base_Case_FINAL_ENG_0_0.pdf
16. Canadian Mental Health Association. *Mental illnesses in children and youth.* 2014. https://cmha.bc.ca/documents/mental-illnesses-in-children-and-youth-2/
17. Government of Canada. *The human face of mental health and mental illness in Canada*. Government of Canada; 2006. https://www.phac-aspc.gc.ca/publicat/human-humain06/pdf/human_face_e.pdf
18. Kessler RC, Berglund P, Demler O, Jin R, Merikangas KR, Walters EE. Lifetime prevalence and age-of-onset distributions of DSM-IV disorders in the National Comorbidity Survey Replication. *Arch Gen Psychiatry*. 2005;62(6):593–602.
19. Georgiades K, Duncan L, Wang L, Comeau J, Boyle MH. Six-month prevalence of mental disorders and service contacts among children and youth in Ontario: evidence from the 2014 Ontario Child Health Study. *Can J Psychiatry*. 2019;64(4):246–55.
20. Merikangas KR, He J ping, Burstein M, Swanson SA, Avenevoli S, Cui L, et al. Lifetime prevalence of mental disorders in US adolescents: results from the National Comorbidity Study-Adolescent Supplement (NCS-A). *J Am Acad Child Adolesc Psychiatry*. 2010;49(10):980–9.
21. Thapar A, Collishaw S, Pine DS, Thapar AK. Depression in adolescence. *Lancet*. 2012;379(9820):1056–67.
22. Gong G, He Y, Evans AC. Brain connectivity: gender makes a difference. *Neuroscientist*. 2011;17(5):575–91.
23. Wiens K, Williams JVA, Lavorato DH, Duffy A, Pringsheim TM, Sajobi TT, et al. Is the prevalence of major depression increasing in the Canadian adolescent population? Assessing trends from 2000 to 2014. *J Affect Disord*. 2017;210:22–6.
24. Wiens K, Bhattarai A, Pedram P, Dores A, Williams J, Bulloch A, et al. A growing need for youth mental health services in Canada: examining trends in youth mental health from 2011 to 2018. *Epidemiol Psychiatr Sci*. 2020;29:e115.
25. Canadian Institute for Health Information. *Children and youth mental health in Canada*. 2022. https://www.cihi.ca/en/children-and-youth-mental-health-in-canada
26. SickKids. *COVID-19: guidance for school operation during the pandemic*. SickKids. 2021. https://www.sickkids.ca/en/news/archive/2021/covid19-updated-guidance-school-operation-during-pandemic/
27. Statistics Canada. *Labour market impacts of COVID-19 on Indigenous people: March to August 2020*. 2020. https://www150.statcan.gc.ca/n1/pub/45-28-0001/2020001/article/00085-eng.htm
28. Gassman-Pines A, Ananat EO, Fitz-Henley J 2nd. COVID-19 and parent-child psychological well-being. *Pediatrics*. 2020;146(4):e2020007294.
29. Dabravolskaj J, Khan MKA, Veugelers PJ, Maximova K. Mental health and wellbeing of 9-12-year-old children in Northern Canada before the Covid-19 pandemic and after the first lockdown. *Int J Public Health*. 2021;1:1604219.
30. Maximova K, Khan M, Dabravolskaj J, Maunula L, Ohinmaa A, Veugelers P. Perceived changes in lifestyle behaviours and in mental health and wellbeing of elementary school children during the first COVID-19 lockdown in Canada. *Public Health*. 2021;202:35-42.
31. United Nations News. *The end of the COVID-19 pandemic is in sight: WHO*. 2022. https://news.un.org/en/story/2022/09/1126621

32. Racine N, McArthur BA, Cooke JE, Eirich R, Zhu J, Madigan S. Global prevalence of depressive and anxiety symptoms in children and adolescents during Covid-19: a meta-analysis. *JAMA Pediatr*. 2021;175(11):1142–50.
33. Viner RM, Ross D, Hardy R, Kuh D, Power C, Johnson A, et al. Life course epidemiology: recognising the importance of adolescence. *J Epidemiol Community Health*. 2015;69(8):719–20.
34. Fuhrmann D, Knoll LJ, Blakemore SJ. Adolescence as a sensitive period of brain development. *Trends Cogn Sci*. 2015;19(10):558–66.
35. Arnett JJ. Emerging adulthood: a theory of development from the late teens through the twenties. *Am Psychol*. 2000;55(5):469–80.
36. Arnett JJ. Emerging adulthood: what is it, and what is it good for? *Child Dev Perspect*. 2007;1(2):68–73.
37. Spring B, Moller AC, Coons MJ. Multiple health behaviours: overview and implications. *J Public Health*. 2012;34(Suppl 1):i3–10.
38. Haye K de la, D'Amico EJ, Miles JNV, Ewing B, Tucker JS. Covariance among multiple health risk behaviors in adolescents. *PLOS One*. 2014;9(5):e98141.
39. Champion KE, Mather M, Spring B, Kay-Lambkin F, Teesson M, Newton NC. Clustering of multiple risk behaviors among a sample of 18-year-old Australians and associations with mental health outcomes: a latent class analysis. *Front Public Health*. 2018;6(101616579):135.
40. Winpenny EM, van Harmelen AL, White M, van Sluijs EMF, Goodyer IM. Diet quality and depressive symptoms in adolescence: no cross-sectional or prospective associations following adjustment for covariates. *Public Health Nutr*. 2018;21(13):2376–84.
41. Radez J, Reardon T, Creswell C, Lawrence PJ, Evdoka-Burton G, Waite P. Why do children and adolescents (not) seek and access professional help for their mental health problems? A systematic review of quantitative and qualitative studies. *Eur Child Adolesc Psychiatry*. 2021;30(2):183–211.
42. Cipriani A, Zhou X, Del Giovane C, Hetrick SE, Qin B, Whittington C, et al. Comparative efficacy and tolerability of antidepressants for major depressive disorder in children and adolescents: a network meta-analysis. *Lancet*. 2016;388(10047):881–90.
43. Hopkins K, Crosland P, Elliott N, Bewley S. Diagnosis and management of depression in children and young people: summary of updated NICE guidance. *Br J Sports Med*. 2016;50(3):184–6.
44. Angold A, Costello EJ. Depressive comorbidity in children and adolescents. *Am J Psychiatry*. 1993;150(12):1779–91.
45. Merikangas KR, Nakamura EF, Kessler RC. Epidemiology of mental disorders in children and adolescents. *Dialogues Clin Neurosci*. 2009;11(1):7–20.
46. Johnson D, Dupuis G, Piche J, Clayborne Z, Colman I. Adult mental health outcomes of adolescent depression: a systematic review. *Depress Anxiety*. 2018;35(8):700–16.
47. Clayborne ZM, Varin M, Colman I. Systematic review and meta-analysis: adolescent depression and long-term psychosocial outcomes. *J Am Acad Child Adolesc Psychiatry*. 2019;58(1):72–9.
48. Colman I, Naicker K, Zeng Y, Ataullahjan A, Senthilselvan A, Patten SB. Predictors of long-term prognosis of depression. *CMAJ*. 2011;183(17):1969–76.

49. Canadian Public Health Association. *A public health approach to population mental wellness.* Ottawa, Canada: Canadian Public Health Association; 2021. https://www.cpha.ca/public-health-approach-population-mental-wellness
50. Canadian Public Health Association. *Review of Canada's initial response to the COVID-19 pandemic*. Ottawa, Canada: Canadian Public Health Association; 2021. https://www.cpha.ca/review-canadas-initial-response-covid-19-pandemic
51. Mendelson T, Eaton WW. Recent advances in the prevention of mental disorders. *Soc Psychiatry Psychiatr Epidemiol*. 2018;53(4):325–39.
52. Saxena S, Hosman C, Jané Llopis E, et al. *Prevention of mental disorders: effective interventions and policy options: summary report*. Geneva: World Health Organization; 2004. https://apps.who.int/iris/bitstream/handle/10665/43027/924159215X_eng.pdf?sequence=1&isAllowed=y
53. Compton MT, Shim RS. Mental illness prevention and mental health promotion: when, who, and how. *Psychiatr Serv.* 2020;71(9):981-3.
54. Le LKD, Esturas AC, Mihalopoulos C, Chiotelis O, Bucholc J, Chatterton ML, et al. Cost-effectiveness evidence of mental health prevention and promotion interventions: a systematic review of economic evaluations. *PLoS Med*. 2021;18(5):e1003606.
55. Fenwick-Smith A, Dahlberg EE, Thompson SC. Systematic review of resilience-enhancing, universal, primary school-based mental health promotion programs. *BMC Psychol*. 2018;6(1):30.
56. Woolf SH. Potential health and economic consequences of misplaced priorities. *JAMA*. 2007;297(5):523–6.
57. Biddle SJH, Pearson N, Ross GM, Braithwaite R. Tracking of sedentary behaviours of young people: a systematic review. *Prev Med*. 2010;51(5):345–51.
58. Lake AA, Mathers JC, Rugg-Gunn AJ, Adamson AJ. Longitudinal change in food habits between adolescence (11–12 years) and adulthood (32–33 years): the ASH30 Study. *J Public Health*. 2006;28(1):10–6.
59. Telama R. Tracking of physical activity from childhood to adulthood: a review. *Obes Facts*. 2009;2(3):187–95.
60. Vermeulen MCM, van der Heijden KB, Kocevska D, Treur JL, Huppertz C, van Beijsterveldt CEM, et al. Associations of sleep with psychological problems and well-being in adolescence: causality or common genetic predispositions? *J Child Psychol Psychiatry*. 2021;62:28–39.
61. Biddle SJH, Ciaccioni S, Thomas G, Vergeer I. Physical activity and mental health in children and adolescents: an updated review of reviews and an analysis of causality. *Psychol Sport Exerc*. 2019;42:146–55.
62. Fergusson DM, Boden JM, Horwood LJ. Tests of causal links between alcohol abuse or dependence and major depression. *Arch Gen Psychiatry*. 2009;66(3):260–6.
63. Kelly Y, Zilanawala A, Booker C, Sacker A. Social media use and adolescent mental health: findings from the UK Millennium Cohort Study. *EClinicalMedicine*. 2018;6:59–68.
64. Afshin A, Sur PJ, Fay KA, Cornaby L, Ferrara G, Salama JS, et al. Health effects of dietary risks in 195 countries, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet*. 2019;393(10184):1958–72.

65. Molendijk M, Molero P, Ortuno Sanchez-Pedreno F, Van der Does W, Angel Martinez-Gonzalez M. Diet quality and depression risk: a systematic review and dose-response meta-analysis of prospective studies. *J Affect Disord*. 2018;226:346–54.
66. Hayward J, Jacka FN, Skouteris H, Millar L, Strugnell C, Swinburn BA, et al. Lifestyle factors and adolescent depressive symptomatology: associations and effect sizes of diet, physical activity and sedentary behaviour. *Aust N Z J Psychiatry*. 2016;50(11):1064–73.
67. O'Neil A, Quirk SE, Housden S, Brennan SL, Williams LJ, Pasco JA, et al. Relationship between diet and mental health in children and adolescents: a systematic review. *Am J Public Health*. 2014;104(10):e31–42.
68. Khalid S, Williams CM, Reynolds SA. Is there an association between diet and depression in children and adolescents? A systematic review. *Br J Nutr*. 2016;116(12):2097–108.
69. Doyle YG, Furey A, Flowers J. Sick individuals and sick populations: 20 years later. *J Epidemiol Community Health*. 2006 May;60(5):396–8.
70. Hernán MA. The C-word: scientific euphemisms do not improve causal inference from observational data. *Am J Public Health*. 2018;108(5):616–9.
71. Ioannidis JP. We need more randomized trials in nutrition—preferably large, long-term, and with negative results. *Am J Clin Nutr*. 2016;103(6):1385–6.
72. Rosen L, Manor O, Engelhard D, Zucker D. In defense of the randomized controlled trial for health promotion research. *Am J Public Health*. 2006;96(7):1181–6.
73. Satija A, Stampfer MJ, Rimm EB, Willett W, Hu FB. Perspective: are large, simple trials the solution for nutrition research? *Adv Nutr*. 2018;9(4):378–87.
74. Satija A, Yu E, Willett WC, Hu FB. Understanding nutritional epidemiology and its role in policy. *Adv Nutr*. 2015;6(1):5–18.
75. Rothman KJ, Greenland S, Lash TL. Modern epidemiology. Vol. 3. Wolters Kluwer Health Lippincott Williams & Wilkins Philadelphia; 2008.
76. Jones DS, Podolsky SH. The history and fate of the gold standard. *Lancet*. 2015;385(9977):1502–3.
77. Molteni R, Barnard RJ, Ying Z, Roberts CK, Gómez-Pinilla F. A high-fat, refined sugar diet reduces hippocampal brain-derived neurotrophic factor, neuronal plasticity, and learning. *Neuroscience*. 2002;112(4):803–14.
78. Wang J, Shao L, Sun X, Young L. Increased oxidative stress in the anterior cingulate cortex of subjects with bipolar disorder and schizophrenia. *Bipolar Disord*. 2009;11(5):523–9.
79. Berk M, Williams LJ, Jacka FN, O'Neil A, Pasco JA, Moylan S, et al. So depression is an inflammatory disease, but where does the inflammation come from? *BMC Medicine*. 2013;11:200.
80. Loughman A, Ponsonby AL, O'Hely M, Symeonides C, Collier F, Tang ML, et al. Gut microbiota composition during infancy and subsequent behavioural outcomes. *EBioMedicine*. 2020;52:102640.
81. Marx W, Lane M, Hockey M, Aslam H, Berk M, Walder K, et al. Diet and depression: exploring the biological mechanisms of action. *Mol Psychiatry*. 2021;26(1):134–50.
82. Molendijk ML, Molero P, Thomas-Odenthal F, van der Does W. There is not much to mediate [yet] when it comes to diet and depression. *Mol Psychiatry*. 2022;27(2):776–7.

83. Thomas-Odenthal F, Molero P, van der Does W, Molendijk M. Impact of review method on the conclusions of clinical reviews: a systematic review on dietary interventions in depression as a case in point. *PLOS One*. 2020;15(9):e0238131.
84. Krieger N. Theories for social epidemiology in the 21st century: an ecosocial perspective. *Int J Epidemiol*. 2001;30(4):668–77.

Chapter 2: Relationship between fruit and vegetables intake and common mental disorders in youth: a systematic review

Dabravolskaj J, Marozoff S, Maximova K, Campbell S, Veugelers PJ. Relationship between fruit and vegetables intake and common mental disorders in youth: a systematic review. *Public Health Rev*. 2022, 43:1604686. doi:10.3389/phrs.2022.1604686

Abstract

Objective: Recent evidence suggests that adequate fruit and vegetables intake (FVI) might be associated with lower risk of common mental disorders (CMDs) in adults, but studies in youth are also beginning to emerge and are synthesized in this systematic review.

Methods: Online databases were searched from inception to October 30, 2020 to locate cross-sectional, cohort, and case-control studies focusing on the FVI and CMDs in youth (i.e., 10-18 years old). The risk of bias of studies was assessed using Joanna Briggs Institute Critical Appraisal Tool and the Newcastle-Ottawa quality assessment scale.

Results: Among 3,944 records identified, 12 studies (8 cross-sectional, 1 case-control, and 3 prospective cohort studies) were included in the final synthesis. None of the prospective cohort studies identified a statistically significant association between FVI and CMDs in youth, although inconsistent associations were reported in cross-sectional and case-control studies.

Conclusions: The lack of associations between FVI and CMDs in youth, along with consistent associations in adults, might be explained by the accumulation of risk theoretical model and methodological challenges.

Introduction

Mental disorders constitute a significant global public health burden[1–3] and result from an intricate interplay of multiple factors. This interplay is particularly potent during adolescence (i.e., 10-19 years old) when more than three-quarters of all life-time mental disorders, especially common mental disorders (CMDs) such as depression and anxiety, manifest for the first time.[4,5] In fact, the cumulative probability of CMDs rises steeply from around 5% in early adolescence to as high as 20% by the end of adolescence.[6] Mental disorders in adolescence are associated with many long-term negative psychosocial outcomes, including low educational attainment, poor work performance,[7] difficulty developing stable relationships and social networks, unemployment,[8] as well as future mental disorders,[9] substance abuse, and suicide.[6] Often underdiagnosed,[4] they can be difficult to manage due to limited effectiveness of available treatment options[10] and high rates of recurrence[6] and comorbidity.[11]

With one in five adolescents living with mental disorders worldwide,[12] there is a recognized need for the development and implementation of effective primary prevention strategies.[13] Recent systematic reviews[14,15] of observational studies point to the association between adherence to high quality diet (i.e., rich in fruit, vegetables, legumes, nuts and whole grains[16]) and lower incidence of CMDs in a general population of youth. However, diet quality is often conceptualized and measured differently, making it difficult to compare results across different studies. To circumvent this challenge, fruit and vegetables intake (FVI) is often used as a simple indicator of overall diet quality.[17]

A systematic review[18] of 16 cross-sectional, 9 cohort, and 2 case-control on the association between FVI and mental disorders in adults showed that the highest category of FVI was associated with up to 17% lower risk of depression in cohort studies, with higher magnitudes of the associations (i.e., up to 25% lower risk of depression) observed in cross-sectional studies. Moreover, every 100-g increase in fruit and vegetable intake was associated with a 3% reduced risk of depression in cohort studies. However, to our knowledge, evidence on this association in adolescents has not yet been synthesized. This paper fills in this gap, with particular attention given to the methodological aspects of available studies to inform future research in the field of nutritional psychiatry in youth.

Methods

Search strategy

A medical librarian (SC) searched the following databases: Prospero, Wiley Cochrane Library, Ovid Embase, Ovid Medline, Ovid PsycInfo, EBSCO CINAHL, ProQuest Dissertations and Theses Global, Food Science and Technology Abstracts (WOS) and CAB Abstracts (WOS). Each of the databases was searched from inception to October 30, 2020. The search strategy included both text words and controlled vocabulary (e.g., MeSH, EMTREE, etc.) for the terms "fruits or vegetables" and "anxiety or depression" (see Appendix A). Studies limited to adults and very young children were excluded. In addition, bibliographies of relevant studies and researcher-identified databases were hand searched. All identified records were exported to Covidence systematic review software,[19] and duplicates were automatically removed (see PRISMA flowchart, Appendix B). Language restriction was not applied; when necessary, a native language speaker was identified in the research community at the University of Alberta

and asked to translate the paper, assess eligibility of the study and extract data. This systematic review was registered on PROSPERO (CRD42020148625, August 1 2020).

Inclusion criteria

Two reviewers (JD and SM) independently reviewed the titles and abstracts on the Covidence platform.[19] JD and SM documented and compared reasons for exclusion. Bibliographies of included papers were reviewed for relevant papers independently by JD and SM. Disagreements during the screening process were resolved by consensus. We included observational (i.e., cohort, case-control, and cross-sectional) studies that focused on FVI, measured combined or separately, and CMDs in community-dwelling adolescents (see detailed inclusion and exclusion criteria in Table 2.1). Inclusion of primary studies was not limited by sex, ethnicity, or any socioeconomic determinants of health. Studies that included adolescents but also extended outside the specified age range (i.e., 10-18 years old) were assessed on a case-by-case basis as to whether they could meaningfully contribute to the systematic review. If data were duplicated in more than one study, only the latest study or the study with the largest sample size was considered. Studies that did not report any estimates of the association of interest and did not provide any data that could be used to calculate any measures of association were excluded.

Data extraction and management

Upon finalizing the list of included studies, JD and SM independently extracted the following data: study details (first author, title, publication year, journal, objectives of the study, study design, follow-up years, study duration, recruitment procedures utilized, description of the exposure(s) and exposure assessment tools, comparator, description of the outcome(s) and

outcome assessment tools, sample size, mean age or age range at baseline, sex of participants included in the study); analysis and results (i.e., statistical methods used to produce the measure and magnitude of association, standard error, standard deviation for the exposure and control groups, 95% CI, p-value, confounders adjusted for in the analysis); and author conclusions. If data in a selected study was missing or lacked sufficient details, JD contacted corresponding authors for additional information. Where the results of several models where presented, data were extracted for all models. Study-specific methods and results (e.g., statistical methods used, comparators, effect measures) are presented in Appendix C.

Risk of bias assessment

The Newcastle-Ottawa quality assessment scale[20] was used to assess the quality of cohort and case-control studies. The Joanna Briggs Institute (JBI) Critical Appraisal Tool for cross-sectional studies[21] was used to assess the quality of cross-sectional studies. One question was excluded from this tool (i.e., "Were objective, standard criteria used for measurement of the condition?"), since the focus was on the general population rather than specific diagnostic methods or clinical populations. As part of the quality assessment process, we assessed whether important confounding factors (particularly, socioeconomic status [SES] which can affect both person's diet and mental health outcomes) were identified and adjusted for in the included studies. Discrepancies resulting from the independent application of quality assessment tools by JD and SM were resolved by consensus. Since the systematic review aimed to map the existing literature and highlight methodological challenges and areas for further research, studies were not excluded based on risk of bias assessment. The utility of introducing a qualitative score has long

been discredited[22]; instead, quality assessments of the selected cross-sectional, cohort and case-control studies are summarized in Table 2.2, 2.3, and 2.4, respectively.

Data analysis and reporting

Considering substantial heterogeneity between studies in terms of study design, exposure and outcome definition and assessment methods, included covariates, measures of association, and results of the risk of bias assessment, the authors refrained from pooling data in a meta-analysis. Moreover, the number of studies available was not sufficient to pool in sub-group analyses. Therefore, a narrative synthesis is provided. The review follows Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) reporting guidelines (Appendix D).

Results

The search yielded 3,944 records to assess for eligibility, 903 duplicates were removed. Among 117 records that were examined in full, 12 studies were included in the final analysis. The articles were published between 2012 and 2020 and included analysis of data collected in the US, UK, Greece, Australia, Canada, South Korea, Saint Lucia, Egypt, Saint Vincent and the Grenadines, Djibouti, Morocco, Myanmar, Zambia, Tanzania, Venezuela, Grenada, Lebanon, China, Indonesia, Thailand, Uganda, Tunisia, Botswana, Sri Lanka, India, Seychelles, Guyana, Ecuador, Jordan, Argentina, and Kenya. Table 2.5 and Appendix C provide detailed information on the study characteristics and results of the included studies, respectively. Eight studies[23–30] used cross-sectional design, three studies[31–33] were prospective cohort studies (two[31,32] included analyses of both cross-sectional and longitudinal data), and one[34] was a case-control study. Sample sizes ranged from 603[32] to 65,528[28] adolescents in cross-sectional studies, from 472[31] to 3757[33] in cohort studies, and 849[34] in the case-control study. Except for one study that focused

exclusively on female youth,[34] all other studies included approximately equal numbers of male and female youth. Age distribution was within the prespecified age limits (i.e., 10-18 years old) in all but one study[25] that included a range of 9-13 year old children attending Grade 5 and 6, with 58% of the sample being older children (11-13 years old).

Only self-reported dietary assessment instruments were used. Eight studies[23–25,27–30,34] assessed intakes of fruit and vegetables separately, while five studies[26,29,31–33] assessed combined FVI. Seven studies[23,24,27–30,34] measured FVI in terms of frequency of FV consumption, while five studies[25,26,31–33] assessed FVI in terms of servings or grams per day. Food frequency questionnaire,[33] four-day diet diary,[32] and 24-hour dietary recall[25] were used in one study each. Single-item dietary assessment questions were part of larger questionnaires on various lifestyle behaviours in nine studies.[23,24,26–31,34] The questions referred to fruit, vegetable, or combined intake in the past 12 months,[33,34] 30 days,[23,29] 7 days,[24,28,30] and the day before.[26,27,31]

All studies assessed depression, two assessed anxiety,[23,29] and one study[33] included common symptoms of depression and anxiety (combined) as the outcome of interest. Six studies used the following validated questionnaires to assess the outcomes of interest: COOPS/WONCA questionnaire,[25] SMFQ,[26,31] CES-D,[27] Korean version of the Beck Depression Inventory,[34] and Moods and Feelings Questionnaire.[32] One study[33] included physician diagnoses of internalizing disorders, and the rest of the studies[23,24,28–30] used single-item self-reported questions to assess the outcome(s) of interest. Subgroup analysis based on gender was conducted in five studies.[25–27,31,32]

Quality assessment

Of 10 cross-sectional studies, eight[23–28,31,32] omitted the criteria for inclusion in the sample, and five[23,24,28–30] did not include validated scales to assess CMDs. Causal claims in respect to the focal association were made in two[23,24] cross-sectional studies. All (except one[24]) studies identified and adjusted for at least some important confounding factors: four studies[25,27,28,30] included indicators of SES and one[23] adjusted for food insecurity, two studies stratified by ethnicity[24] and gender.[31]

There was one[34] case-control study. Community controls with no history of disease were selected from the same source population as the cases (i.e., adolescent youth attending the university health centre for annual routine health examinations). FFQ with 63 food items and the Korean version of the Beck Depression Inventory (K-BDI) were included in the same questionnaire. Importantly, participants with pre-existing psychological conditions or those taking medication for depression were excluded from the study. Some of the most important confounding factors, such as SES, familial history of depression and physical activity, were not measured. It is unclear whether assessors were blinded to the research question or outcome assessment.

Among three prospective cohort studies, samples were representative of 10-11 year old children in corresponding communities in one study.[33] In all cohort studies, non-exposed cohorts were drawn from the same community as exposed cohorts and samples appeared free from mental disorders at the beginning of the studies. All studies ascertained exposure using self-reported dietary measures, and in all but one[33] mental disorders were self-reported. One study[31] included a two-year follow-up, while the other two studies included three-year[32,33] follow-ups. One study[33]

had complete follow up. Another study[31] had 74.5% participation rate, but participants lost to follow-up (3.2% refusal, 7.2% unavailable, 15.1% relocated) were unlikely to introduce bias. One study[32] reported a follow-up rate of less than 70%; the analysis of differences between participants and non-participants was not available, making it difficult to assess the possibility of selection bias. All studies adjusted for sex/gender. Other confounding factors adjusted for included: parental education, and the school participants attended[31]; age, SES, other lifestyle behaviours (smoking, physical activity, alcohol consumption, sleep), friendship quality, self-esteem, family functioning, %body fat, medication use, total energy intake, and depression symptoms at baseline[32]; and household income, parental marital status, parental education, body weight status, physical activity and geographic area.[33]

F&V intakes (measured separately) and depression

Eight studies (seven cross-sectional[23–25,27–30] and one case-control[34]) reported inconsistent associations between fruit and vegetable intakes and depression symptoms. For example, the study by Liu et al.[29] that analyzed the association between depression and fruit and vegetable intakes in 25 low- and middle-income countries reported statistically significant associations. While the associations between fruit intake and depression were statistically significant for some countries (e.g., Tanzania, China, Indonesia, Thailand, India, Seychelles, Ecuador, and Jordan), they were not statistically significant for other low- and middle-income countries (Saint Lucia, Egypt, Saint Vincent and the Grenadines, Djibouti, Morocco, Myanmar, Zambia, Venezuela, Grenada, Lebanon, Uganda, Tunisia, Botswana, Sri Lanka, Guyana, Argentina, and Kenya). Associations in all listed countries were adjusted for different potential confounding factors. Liu et al. pooled data from all studies in a meta-analysis: fruit intake of <2 times and 2 or more

times/day versus none was associated with 0.79 (0.73; 0.86) and 0.75 (0.68, 0.82) times lower odds of depression, respectively. Vegetable intake of <3 times/day and 3 or more times per day vs none was associated with 0.74 (0.67; 0.83) and 0.75 (0.68; 0.84) times lower odds of depression, respectively.

FVI (combined) and depression

Four studies reported on the association between combined FVI and depression. Two studies were cross-sectional, while two others included both cross-sectional and longitudinal analyses. One cross-sectional study[29] reported statistically significant associations in four of 25 low- and middle-income countries (i.e., Seychelles, Ecuador, Jordan, Kenya). One prospective study reported non-significant associations in univariate analyses: OR=0.87 (95% CI 0.39; 1.96) for males and OR=0.85 (95% CI 0.54; 1.34) for females.[31] Another prospective cohort study reported no statistically significant associations following adjustment for covariates: β=0.14 (95% CI of -0.15; 0.43).[32]

F&V intakes (measured separately) and anxiety

Two studies[23,29] examined the associations between fruit and vegetable intakes and anxiety. Arat[23] reported results for six of the low- and middle-income countries and found statistically significant associations in Botswana, Kenya (for fruit but not vegetable intake as the exposure of interest), Seychelles, Uganda, Tanzania, and Zambia. Another study by Liu et al.[29] used data from the same questionnaire as Arat,[23] although for a narrower age range, reporting statistically significant associations between fruit intake and anxiety for Morocco, Tanzania, Venezuela China, Indonesia, Uganda, Tunisia, Sri Lanka, India, Ecuador, Jordan, Argentina, Kenya; and

between vegetable intake and anxiety in Saint Vincent and the Grenadines, Djibouti, Lebanon, China, Seychelles and Ecuador. When the measures of association were combined in a meta-analysis, the fruit intake of <2 times/day and 2 or more times a day compared to no intake was associated with 0.60 (0.54; 0.67) and 0.61 (0.54, 0.68) times lower odds of anxiety, while vegetable intake of <3 times/day and 3 or more times a day versus no intake was associated with 0.71 (0.63; 0.81) and 0.87 (0.73; 1.03) times lower odds of having anxiety symptoms. Neither of the studies reported on the association between the combined FVI and anxiety.

FVI (combined) and depression and anxiety (combined)

One study[33] concluded that there was no statistically significant association between FVI and internalizing disorders when comparing 2nd tertile to 1st tertile (IRR 1.04, 95% CI 0.71; 1.53) and 3rd tertile to 1st tertile (IRR 1.25, 95% CI 0.8; 1.99). Analyses were adjusted for energy intake, gender, household income, parental marital status and education, body weight status, physical activity, and geographical area.

Discussion

Fruit and vegetables have long been recognized for their beneficial effects on gastrointestinal health, weight management, prevention of cardiovascular and metabolic disorders, respiratory health, and high bone mineral density, among other conditions and diseases.[35] Moreover, FVI has recently been shown to be associated with lower risk of mental disorders in the general population.[18,36] However, our systematic review did not confirm previous claims for the existing association between FVI and CMDs specifically in youth. Among 12 identified studies, one case-control and some of the cross-sectional studies pointed to significant associations between

FVI and CMDs in youth, while none of the three prospective cohort studies showed significant associations after adjusting for confounding factors.

Previously proposed biological mechanisms to explain the association between FVI and CMDs revolve around the high content of fiber, nutrients (e.g., vitamin C), and phytochemicals (e.g., polyphenols, carotenoids)[35] found in vegetables and fruits, which are believed to have beneficial effects on neurotransmitter systems, neuronal plasticity,[37] and gut health.[38–40] Although the aforementioned biological mechanisms appear plausible and are supported by studies in adults, the effects of FVI on CMDs may differ in youth due to the rapid brain development during adolescence.[41] Another potential explanation involves one of the existing theoretical models derived from life course epidemiology – i.e., the accumulation of risk model.[42] This model states that every additional year of exposure is associated with an increased risk of poor outcomes: this could explain why the association between FVI and CMDs becomes apparent later in life. Further research looking at the diet-mental health relationship through the lens of life course epidemiology is warranted. Methodological challenges, discussed below, could also explain our findings.

Consistent with other literature on the diet-mental health relationship,[15,18,43] cross-sectional study design was the one most commonly used. While the cross-sectional study design can help generate hypotheses, in respect to the diet-mental health relationship this task has already been fulfilled. The inability to determine the temporal order of diet and mental disorders makes this study design of limited value to any etiological inferences.[44] Moreover, cross-sectional studies identified in this systematic review provided inconsistent conclusions, potentially due to

adjusting for different confounding factors. As for the case-control study,[34] the authors excluded those with pre-existing mental disorders, thus partly tackling the issue of reverse causality, but we cannot exclude the possibility of recall bias. Both exposure and outcome were assessed at the same time, and the study did not report whether those who completed the dietary assessment were blinded to participants' outcomes or the research question itself. Given the aforementioned limitations inherent to cross-sectional and case-control study designs and in the absence of prevention trials (in part due to ethical and feasibility concerns), attention and efforts should be redirected to planning and conducting rigorous prospective cohort studies. We identified three prospective cohort studies and, given the incremental nature of research, more prospective cohort studies that address the methodological issues outlined below would be of value.

First of all, SES is an established confounder linked to both diet and mental disorders and therefore should be controlled for in all studies investigating this focal relationship; SES was measured and adjusted for in two[32,33] out of three cohort studies included in this systematic review. At the same time, some of the variables (e.g., weight status indicators) that were treated as confounding factors could well be intermediate variables that we should not control for. Additionally, it is important to consider the nature of confounding factors (e.g., time-invariant such as ethnicity, race, sex vs. time-variant such as food security, parental mental health, family functioning), which could inform the choice of analytical methods (e.g., parametric G-formula) other than the standard regression models (e.g., linear and logistic regression models). Employing directed acyclic graphs[45] could help guide these pre-analysis steps and identify appropriate adjustment sets, minimize inappropriate adjustment, and invite external scrutiny to enhance the quality of work.

In addition, there are measurement errors associated with both self-reported diet and mental disorders. Given the potential for recall and social desirability biases associated with self-report measures, sensitivity analyses to delineate the effects of measurement errors on the focal relationship are needed.[46] Adjustment for total energy intake is another strategy that has been strongly recommended to partially correct for the measurement error associated with self-reported dietary intake. Moreover, fruit juice is excluded from recent healthy eating recommendations due to excess free sugars they contain;[47] for this reason, consumption of fruit juice should not count toward FVI. In addition, validated questionnaires, as opposed to single-item screener questions, should be preferred for the assessment of mental health disorders. Lastly, despite pronounced sex differences in both the prevalence of mental disorders[48] and eating behaviours and diet,[49,50] sub-group analysis was done in less than half of the included studies, and further exploration of potential effect modification is of value.

Conclusion

This systematic review showed that while inconsistent associations between FVI and CMDs in youth were reported in cross-sectional and case-control studies, no association was detected in prospective cohort studies. This evidence differs from what has recently been concluded in a systematic review on the association between FVI and depression in adults,[18] which can be explained by the accumulation of risk theoretical model of the development of mental disorders and/or methodological challenges outlined in the paper.

Table 2.1. Inclusion and exclusion criteria.

	Inclusion criteria	**Exclusion criteria**
Population	Community-dwelling 10-18 years old adolescents; general population if the association was studied in adolescents as part of subgroups analyses.	Non-human subjects; institutionalized adolescents; studies focusing solely on children (<10 years old) or adults (≥19 years old).
Exposure of interest	FVI measured in terms of frequency of consumption or servings or grams per day (80g was considered one serving[51]).	Other diet constructs (e.g., eating behaviors) considered alone, rather than in combination with FVI.
Outcome of interest	Common mental disorders (i.e., depression, anxiety, or co-morbid depression and anxiety), as diagnosed by physicians, using validated tools, or self-reporting.	Other mental disorders (including those with anxiety and/or depressive components, eating disorders, psychological distress, attention deficit hyperactivity disorder). For studies where outcomes were measured with a single question (as opposed to a validated scale), reviewers assessed if the question explicitly stated or implied mental disorders other than the outcome of interest.

Table 2.2. Quality assessment of cross-sectional studies included in the systematic.

Cross-sectional studies	**Were the criteria for inclusion in the sample clearly defined?**	**Were the study subjects and the setting described in detail?**	**Was the exposure measured in a valid and reliable way?**	**Were confounding factors identified?**	**Were strategies to deal with confounding factors stated?**	**Were the outcomes measured in a valid and reliable way?**	**Was appropriate statistical analysis used?**
Arat 2017	No	No	Yes	Yes	Yes	No	Yes
Arat 2015	No	No	Yes	No	No	No	No
Hoare et al. 2019	No	Yes	Yes	Yes	Yes	Yes	Yes
Hoare et al. 2014	No	Yes	Yes	Yes	Yes	Yes	Yes
Hoare et al. 2018	No	Yes	Yes	Yes	Yes	Yes	Yes
Hoare et al. 2016	No	Yes	Yes	Yes	Yes	Yes	Yes
Hong & Peltzer 2017	No	Yes	Yes	Yes	Yes	No	Yes
Liu et al. 2020	Yes	Yes	Yes	Yes	Yes	No	Yes
Park et al. 2018	Yes	Yes	Yes	Yes	Yes	No	Yes
Winpenny et al. 2018	No	Yes	Yes	Yes	Yes	Yes	Yes

Table 2.3. Quality assessment of cohort studies included in the systematic review.

Cohort studies	**Representativeness of the exposed cohort: A: truly representative of the average (describe) in the community; B: somewhat representative of the average in the community; C: selected group of users; D: no description of the derivation of the cohort**	**Selection of the non exposed cohort: A: drawn from the same community as the exposed cohort; B: drawn from a different source; C: no description of the derivation of the non exposed cohort**	**Ascertainment of exposure: A: secure record; B: structured interview; C: written self report; D: no description**	**Demonstration that outcome of interest was not present at start of study: A: yes; B: no.**	**Comparability of cohorts on the basis of the design or analysis: A: study controls for socioeconomic status; B: study controls for any additional factor**	**Assessment of outcome: A: independent blind assessment; B: record linkage; C: self report; D: no description**	**Was follow-up long enough for outcomes to occur: A: yes; B: no**	**Adequacy of follow up of cohorts: A: complete follow up - all subjects accounted for; B: subjects lost to follow up unlikely to introduce bias (≥70% follow-up) or description provided of those lost; C: follow up rate < 70% and no description of those lost; D: no statement**
Hoare et al. 2016	B	A	C	A	B	C	A (2 years)	B
McMartin et al. 2012	A	A	C	A	A and B	B	A (3 years)	A
Winpenny et al. 2018	B	A	C	A	A and B	C	A (3 years)	C

Table 2.4. Quality assessment of case-control studies included in the systematic review.

Case-control studies	Is the case definition adequate: A: yes, with independent validation; B: yes (e.g., record linkage, self reports); C: no description	Representativeness of the cases: A: consecutive or obviously representative series of cases; B: potential for selection biases or not stated	Selection of controls: A: community controls; B: hospital controls; C: no description	Definition of controls: A: no history of disease (endpoint); B: no description of source	Comparability of cases and controls on the basis of the design or analysis: A: study control for socioeconomic status; B: study controls for additional factors	Ascertainment of exposure (A: secure record (e.g., surgical records); B: structured interview blinded to case/control status; C: interview not blinded to case/control status; D: written self report or medical record only; E: no description	Same method of ascertainment for cases and control: A: yes; B: no	Non-response rate: A: same rate for both groups; B: non respondents described; C: rate different and no designation.
Kim et al. 2015	B	B	A	A	B	D	A	C

Table 2.5. Description of studies included in the systematic review.

Author(s) and publication year	Study design	Country	Sample size	Mean age or age range (at baseline if a cohort study)	% females	Follow-up years	Exposure(s)	Outcome(s)	Comments and conclusions
Arat 2017	Cross-sectional	Botswana	2,197	11-17 years old	55%	N/A	F, V: Single-item dietary measure as part of the GSHS "During the past 30 days, how many times per day did you usually eat fruit?" and "During the past 30 days, how many times per day did you usually eat vegetable?"	Depression and anxiety assessed by single questions: "During the past 12 months, did you ever feel so sad or hopeless almost every day for 2 weeks or more in a row that you stopped doing your usual activities?" and "During the past 12 months, how often have you been so worried about something that you could not sleep at night?"	"… higher fruit intake as a risk factor for depression, anxiety (except the United Republic of Tanzania)… higher vegetable consumption as a risk factor for depression, anxiety (except the United Republic of Tanzania and Zambia)…"
		Kenya	3,691		51.3%				
		Seychelles	1,432		52.2%				
		Uganda	3,215		48.8%				
		Tanzania	2,176		52.1%				
		Zambia	2,257		51.1%				
Arat 2015	Cross-	US	10,563	12-18	Asian	N/A	F, V: Single-	Depression	No association

	sectional			years old	American 52.2%, African American 49.6%, Caucasian 47.7%		item dietary measure as part of the YRBS "During the past 7 days, how many times did you eat fruit?"); "During the past 7 days, how many times did you eat other vegetables? (Do not count green salad, potatoes, or carrots.)"	assessed by a single question: "During the past 12 months, did you ever feel so sad or hopeless almost every day for two weeks or more in a row that you stopped doing some usual activities?"	between F and V intake and depression; however, causal language throughout the article (e.g. "risk factors for depression specific to Asians, and not Caucasians or Africans, was lower carrot consumption").
Hoare et al. 2019	Cross-sectional	Greece	2,240	9-13 years old	50%	N/A	F, V: 24-hour recall morning interviews conducted by trained dietitians and nutritionists on 2 consecutive weekdays and 1 weekend day.	Emotional functioning (i.e., depression) assessed by COOPS/WONCA questionnaire: "During the past 2 weeks, how much were you pre-occupied with emotional problems such as feeling anxious, depressed, irritable or	"There were no association observed between the consumption of fruits and vegetables and emotional functioning."

								downhearted and sad?'	
Hoare et al. 2014	Cross-sectional	Australia	800	11.8-14.9 years old	55%	N/A	FV: single item dietary measure as part of the ABAKQ "How many servings of fruit/vegetables they consumed on the last school day, including those eaten at home?"	Depression assessed by the SMFQ	"neither fruit and vegetable nor takeaway food consumption were related to depressive symptomatology in multivariate analyses."
Hoare et al. 2018	Cross-sectional[1]	US	3,696	15.9 (1.7)	Both males and females were included in the sample, but %females not reported	N/A	F, V: Single-item dietary measure "How often did you eat fruit or drink fruit juice yesterday?" and the same question for vegetable consumption.	Depression assessed by the 20-item CES-D	"Fruit consumption was cross-sectionally related to reduced odds of depression in adolescence in both males and females, both before and after controlling for covariates. Vegetable consumption

[1] The study by Hoare et al. 2018 also included prospective cohort data with the outcome of interest being adult depression. We omitted this part due to the nature of this systematic review. Moreover, there is an overlap between data used in Hoare et al. 2014 and data used for cross-sectional analysis in Hoare et al. 2016. Both studies are included in this systematic review given that the sample size in Hoare et al. 2014 was 800 compared to 634 in Hoare et al. 2016.

									among females was cross-sectionally associated with reduced odds of depression in adolescence."
Hoare et al. 2016	1) Cross-sectional and 2) prospective cohort	Australia	634	13.1 (0.6)	53.3%	Wave 1 (May 2012), Wave 2 (May 2014)	FV: "How many servings of fruit/ vegetables they consumed on the last school day, including those eaten at home?" as part of the ABAKQ	Depression assessed by the SMFQ	FVI was not a significant predictor in univariate analysis, hence not entered in further models and not commented on.
Hong & Peltzer 2017	Cross-sectional	Korea	65,528	12-18 years old (mean age 15.1)	47.8%	N/A	F, V: single-item dietary measure as part of KYRBS Participants were asked about the frequency of fruits (excluding fruit juices) and vegetable dishes (excluding Kimchi) over the past 7 days	Depression symptoms assessed by a single question: "Have you experienced sadness or despair to the degree that you stopped your daily routine for the recent 12 months?"	"Positive dietary behaviours (fruit and vegetable consumption…) were negatively associated with perceived stress and depression symptoms."

Kim et al. 2015	Case-control	Korea	849	15 (1.5)	100%	N/A (depressive symptoms were assessed during recruitment, while data on dietary patterns was obtained by FFQ in the past 12 months)	F, V: FFQ for the KYRBS; frequency range of the FFQ items in the past 12 months was classified into nine categories (never or seldom, once per month, 2-3 times per month, once per week, 2-4 times per week, 5-6 times per week, once per day, twice per day and three times per day) and the portion size was divided into three categories (small, medium and large).	Depression assessed by the Korean version of the Beck Depression Inventory	"…consumption of green vegetables and 1 to 3 servings/day of fruits was associated with decreased risk of depression."
Liu et al. 2020	Cross-sectional	25 low- and middle-	65,267	12-15 years old	Country-specific, ranging	N/A	F, V, FV: Single-item measure as part	Depressive and anxiety symptoms	When country-specific estimates were

	income countries[2], see below			between 40.5% to 57.9%	of the GSHS "During the past 30 days, how many times per day did you usually eat fruit, such as apples, bananas, oranges?" and "During the past 30 days, how many times per day did you usually eat vegetables, such as salads, spinach, eggplant, tomatoes, and cucumbers?"	assessed by a single question: "During the past 12 months, did you ever feel so sad or hopeless almost every day for two weeks or more in a row that you stopped doing your usual activities?" and "During the past 12 months, how often have you been so worried about something that you could not sleep at night?"	combined in a meta-analysis, inadequate vs adequate FVI was associated with a higher risk of depressive symptoms but not anxiety symptoms"
	Saint Lucia	1,032	13.7	55.6%			
	Egypt	4,476	13.2	48.5%			
	Saint Vincent and Grenadines	1,124	13.5	54.2%			
	Djibouti	928	14.3	40.5			
	Morocco	1,916	14	47.9			
	Myanmar	2,212	13.6	50.5			
	Zambia	1,201	13.9	49.7			
	United Republic of Tanzania	1,712	13	53.9			
	Venezuela	3,827	13.2	52.8			
	Grenada	1,244	13.7	57.9			
	Lebanon	4,415	13.6	53			
	China	8,313	13.7	49.6			
	Indonesia	2,979	13.8	50.7			
	Thailand	2,570	13.6	52.7			
	Uganda	1,839	14.3	52.9			
	Tunisia	2,474	13.6	50.6			
	Botswana	1,336	14.3	54.4			
	Sri Lanka	2,435	13.7	50.5			
	India	7,120	13.9	42.5			
	Seychelles	1,095	13.6	50.9			

[2] Saint Lucia, Egypt, Saint Vincent and Grenadines, Djibouti, Morocco, Myanmar, Zambia, United Republic of Tanzania, Venezuela, Grenada, Lebanon, China, Indonesia, Thailand, Uganda, Tunisia, Botswana, Sri Lanka, India, Seychelles, Guyana, Ecuador, Jordan, Argentina, Kenya

		Guyana	1,027	14.1	53.7				
		Ecuador	4,281	13.4	51.6				
		Jordan	1,542	14.4	54.5				
		Argentina	1,475	14.1	54.4				
		Kenya	2,694	13.9	53.4				
McMartin et al. 2012	Prospective cohort	Canada	3,757	10-11 years old	52%	Wave 1 (2003), Wave 2 (2006)	FV: FFQ over the past 12 months; number of daily servings of FV	Internalizing disorders that include common symptoms of depression and anxiety assessed by physician diagnosis	"none of the food items and nutrients including vegetable and fruit consumption… showed a statistically significant association with internalizing disorders."
Park et al. 2018	Cross-sectional	Korea	65,528	14.99 (1.74)	48.4%	N/A	F, V: single-item dietary measure as part of the KYRBS how often students engaged in each dietary behaviour within the past 7 days	Depression symptoms assessed by a single question: "In the past 12 months, have you ever felt depression or hopelessness severe enough to compromise your daily activities during 2 weeks or more?"	"…healthier dietary behaviour [including frequent fruits (1 or more servings a day) and vegetables (3 or more times a day) consumption] was associated with … lower odds of perceived stress

									and depressive mood."
Winpenny et al. 2018	Prospective cohort (with longitudinal and cross-sectional analysis)	UK	603	14.05 (0.3)	60%	Wave 1 (2005-2007), Wave 2 (3 years later)	FV: 4 d diet diary, including two weekdays and two weekend days, reporting estimated portion sizes in terms of small, medium or large, household measures or as individual items.	Depression assessed by the Moods and Feelings Questionnaire	"There were no significant associations between … fruit and vegetable intake… and depressive symptoms at baseline, nor … at 3-year follow up, after controlling for covariates."

Abbreviations: ABAKQ – Adolescent Behaviours, Attitudes, and Knowledge Questionnaire; CES-D – Center for Epidemiologic Studies Depression Scale; COOPS/WONCA – Dartmouth COOP Functional Health Assessment charts/World Organization of Family Doctors; F – fruit intake, V – vegetables intake, FV – fruit and vegetables combined intake; GSHS – Global School-based Health Survey; KYRBS – Korea Youth Risk Behaviour Web-based Survey; N/A – not applicable; NR – not reported; SMFQ - Moods and Feelings Questionnaire – Short Form; ERBS – Youth Risk Behaviour Survey.

References

1. National Institute of Mental Health. *Mental illness definitions*. 2022. https://www.nimh.nih.gov/health/statistics/mental-illness.shtml
2. Vigo D, Thornicroft G, Atun R. Estimating the true global burden of mental illness. *Lancet Psychiatry.* 2016:3(2):171–8.
3. World Health Organization. *Global burden of mental disorders and the need for a comprehensive, coordinated response from health and social sectors at the country level*. Geneva, Switzerland: World Health Organization; 2012. https://apps.who.int/iris/bitstream/handle/10665/78898/A65_10-en.pdf?sequence=1&isAllowed=y
4. Kessler RC, Berglund P, Demler O, Jin R, Merikangas KR, Walters EE. Lifetime prevalence and age-of-onset distributions of DSM-IV disorders in the National Comorbidity Survey Replication. *Arch Gen Psychiatry*. 2005;62(6):593–602.
5. Merikangas KR, He JP, Burstein M, Swanson SA, Avenevoli S, Cui L, et al. Lifetime prevalence of mental disorders in US adolescents: results from the National Comorbidity Study-Adolescent Supplement (NCS-A). *J Am Acad Child Adolesc Psychiatry*. 2010;49(10):980–9.
6. Thapar A, Collishaw S, Pine DS, Thapar AK. Depression in adolescence. *Lancet.* 2012;379(9820):1056–67.
7. Johnson D, Dupuis G, Piche J, Clayborne Z, Colman I. Adult mental health outcomes of adolescent depression: a systematic review. *Depress Anxiety.* 2018;35(8):700–16
8. Clayborne ZM, Varin M, Colman I. Systematic review and meta-analysis: adolescent depression and long-term psychosocial outcomes. *J Am Acad Child Adolesc Psychiatry*. 2019;58(1):72–9.
9. Colman I, Naicker K, Zeng Y, Ataullahjan A, Senthilselvan A, Patten SB. Predictors of long-term prognosis of depression. *CMAJ.* 2011;183(17):1969–76.
10. Cipriani A, Zhou X, Del Giovane C, Hetrick SE, Qin B, Whittington C, et al. Comparative efficacy and tolerability of antidepressants for major depressive disorder in children and adolescents: a network meta-analysis. *Lancet*. 2016;388(10047):881–90.
11. Angold A, Costello EJ. Depressive comorbidity in children and adolescents. *Am J Psychiatry*. 1993;150(12):1779–91.
12. Kessler RC, Bromet EJ. The epidemiology of depression across cultures. *Annu Rev Public Health*. 2013;34:119–38.
13. McDaid D, Park AL, Wahlbeck K. The economic case for the prevention of mental illness. *Annu Rev Public Health.* 2019;40(1):373–89.
14. O'Neil A, Quirk SE, Housden S, Brennan SL, Williams LJ, Pasco JA, et al. Relationship between diet and mental health in children and adolescents: a systematic review. *Am J Public Health.* 2014;104(10):e31–42.
15. Khalid S, Williams CM, Reynolds SA. Is there an association between diet and depression in children and adolescents? A systematic review. *Br J Nutr.* 2016;116(12):2097–108.
16. World Health Organization. *Healthy diet*. 2020. Geneva, Switzerland: World Health Organization; 2020. https://www.who.int/news-room/fact-sheets/detail/healthy-diet
17. Garriguet D. Diet quality in Canada. *Health Rep.* 2009;20(3):41–52.
18. Saghafian F, Malmir H, Saneei P, Milajerdi A, Larijani B, Esmaillzadeh A. Fruit and vegetable consumption and risk of depression: accumulative evidence from an updated

systematic review and meta-analysis of epidemiological studies. *Br J Nutr*. 2018;119(10):1087–101.
19. Veritas Health Innovation. *Covidence systematic review software*. Melbourne, Australia
20. Wells GA, Shea B, O'Connell D, Peterson J, Welch V, Losos M, et al. The Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses (2008). http://www.ohri.ca/programs/clinical_epidemiology/oxford.asp
21. *Appendix 7.5. Critical appraisal checklist for analytical cross-sectional studies - JBI Reviewer's Manual*. https://wiki.joannabriggs.org/display/MANUAL/Appendix+7.5+Critical+appraisal+checklist+for+analytical+cross-sectional+studies
22. Greenland S. Quality scores are useless and potentially misleading. *Am J Epidemiol.* 1994;140(3):300–1.
23. Arat G. The link between nutrition and mental Health in Sub-Saharan African adolescents: findings from the Global School-Based Health Survey. *Glob Soc Welf*. 2017;4(1):31–40.
24. Arat G. Emerging protective and risk factors of mental health in Asian American students: findings from the 2013 Youth Risk Behavior Survey. *Vulnerable Child Youth Stud.* 2015;10(3):192–205.
25. Hoare E, Marx W, Firth J, McLeod S, Jacka F, Chrousos GP, et al. Lifestyle behavioural risk factors and emotional functioning among schoolchildren: The Healthy Growth Study. *Eur Psychiatry J Assoc Eur Psychiatr*. 2019;61:79–84.
26. Hoare E, Millar L, Fuller-Tyszkiewicz M, Skouteris H, Nichols M, Jacka F, et al. Associations between obesogenic risk and depressive symptomatology in Australian adolescents: a cross-sectional study. *J Epidemiol Community Health.* 2014;68(8):767–72.
27. Hoare E, Hockey M, Ruusunen A, Jacka FN. Does fruit and vegetable consumption during adolescence predict adult depression? A longitudinal study of US adolescents. *Front Psychiatry*. 2018;9:581.
28. Hong SA, Peltzer K. Dietary behaviour, psychological well-being and mental distress among adolescents in Korea. *Child Adolesc Psychiatry Ment Health*. 2017;11(101297974):56.
29. Liu MW, Chen QT, Towne SD, Zhang J, Yu HJ, Tang R, et al. Fruit and vegetable intake in relation to depressive and anxiety symptoms among adolescents in 25 low- and middle-income countries. *J Affect Disord*. 2020;261:172–80.
30. Park S, Rim SJ, Lee JH. Associations between dietary behaviours and perceived physical and mental health status among Korean adolescents. *Nutr Diet J Dietit Assoc Aust*. 2018;75(5):488–93.
31. Hoare E, Millar L, Fuller-Tyszkiewicz M, Skouteris H, Nichols M, Malakellis M, et al. Depressive symptomatology, weight status and obesogenic risk among Australian adolescents: a prospective cohort study. *BMJ Open*. 2016;6(3):e010072.
32. Winpenny EM, van Harmelen AL, White M, van Sluijs EMF, Goodyer IM. Diet quality and depressive symptoms in adolescence: no cross-sectional or prospective associations following adjustment for covariates. *Public Health Nutr*. 2018;21(13):2376–84.
33. McMartin SE, Kuhle S, Colman I, Kirk SF, Veugelers PJ. Diet quality and mental health in subsequent years among Canadian youth. *Public Health Nutr*. 2012;15(12):2253–8.
34. Kim TH, Choi J young, Lee HH, Park Y. Associations between dietary pattern and depression in Korean adolescent girls. *J Pediatr Adolesc Gynecol*. 2015;28(6):533–7.
35. Dreher ML. Whole fruits and fruit fiber emerging health effects. *Nutrients*. 2018;10(12):1833.

36. Liu X, Yan Y, Li F, Zhang D. Fruit and vegetable consumption and the risk of depression: A meta-analysis. *Nutrition*. 2016;32(3):296–302.
37. Molteni R, Barnard RJ, Ying Z, Roberts CK, Gómez-Pinilla F. A high-fat, refined sugar diet reduces hippocampal brain-derived neurotrophic factor, neuronal plasticity, and learning. *Neuroscience*. 2002;112(4):803–14.
38. Kim YK, Shin C. The microbiota-gut-brain axis in neuropsychiatric disorders: pathophysiological mechanisms and novel treatments. *Curr Neuropharmacol*. 2018;16(5):559–73.
39. Taylor AM, Holscher HD. A review of dietary and microbial connections to depression, anxiety, and stress. *Nutr Neurosci*. 2020;23(3):237-250.
40. Nguyen B, Ding D, Mihrshahi S. Fruit and vegetable consumption and psychological distress: cross-sectional and longitudinal analyses based on a large Australian sample. *BMJ Open*. 2017;15;7(3):e014201.
41. Best O, Ban S. Adolescence: physical changes and neurological development. *Br J Nurs*. 2021;30(5):272–5.
42. Evans GW, Li D, Whipple SS. Cumulative risk and child development. *Psychol Bull*. 2013;139(6):1342–96.
43. Molendijk M, Molero P, Ortuno Sanchez-Pedreno F, Van der Does W, Martinez-Gonzalez MA. Diet quality and depression risk: a systematic review and dose-response meta-analysis of prospective studies. *J Affect Disord*. 2018;226:346–54.
44. Rothman KJ, Greenland S, Lash TL. Modern epidemiology. Vol. 3. Wolters Kluwer Health, Lippincott Williams & Wilkins Philadelphia. 2008.
45. Tennant PW, Murray EJ, Arnold KF, Berrie L, Fox MP, Gadd SC, et al. Use of directed acyclic graphs (DAGs) to identify confounders in applied health research: review and recommendations. *Int J Epidemiol*. 2021;50(2):620-32.
46. Reedy J, Subar AF, George SM, Krebs-Smith SM. Extending methods in dietary patterns research. *Nutrients*. 2018;10(5).
47. Health Canada. *Section 2: Foods and beverages that undermine healthy eating. Canada Food Guide*. 2022. https://food-guide.canada.ca/en/guidelines/section-2-foods-and-beverages-undermine-healthy-eating/
48. Georgiades K, Duncan L, Wang L, Comeau J, Boyle MH. Six-month prevalence of mental disorders and service contacts among children and youth in Ontario: evidence from the 2014 Ontario Child Health Study. *Can J Psychiatry*. 2019;64(4):246–55.
49. Caine-Bish NL, Scheule B. Gender differences in food preferences of school-aged children and adolescents. *J Sch Health*. 2009;79(11):532–40.
50. Keller KL, Kling SMR, Fuchs B, Pearce AL, Reigh NA, Masterson T, et al. A biopsychosocial model of sex differences in children's eating behaviors. *Nutrients*. 2019;11(3):682.
51. World Health Organization. *Fruit and vegetables for health. Report of a Joint FAO/WHO Workshop*. Kobe, Japan: World Health Organization; 2004. http://www.fao.org/3/a-y5861e.pdf

Chapter 3: Investigating the association between diet and mental health outcomes in middle adolescence using the directed acyclic graph-informed regression modelling

Dabravolskaj J, Patte KA, Yamamoto S, Leatherdale ST, Veugelers PJ, Maximova K. Investigating the association between diet and mental health outcomes in middle adolescence using the directed acyclic graph-informed regression modelling. [to be submitted]

Abstract

Background: The high burden of mental disorders in adolescents calls for population-level prevention and promotion interventions. One currently understudied target of such interventions is diet. Using data from a large longitudinal study of Canadian adolescents (14-18 years old), we examined the prospective associations between diet and mental health outcomes.

Methods: We created a causal model that informed linear mixed-effects models to estimate the effect of diet (i.e., vegetables and fruit and sugar-sweetened beverages [SSBs] consumption) at baseline (2017/18) on depressive and anxiety symptoms and psychological wellbeing (measured by the CESD-R-10, GAD-7, and Flourishing Scale, respectively) at 1-year follow-up (2018/19) in a sample of 13,887 Canadian high school students who participated in the Cannabis, Obesity, Mental health, Physical activity, Alcohol, Smoking, and Sedentary behaviour (COMPASS) study. Analyses were adjusted for variables deemed confounders in the causal model (i.e., mental health at baseline, weekly spending money, age, eating behaviours, lifestyle behaviours, social support). Sensitivity analyses assessed the robustness of the effect estimates to unmeasured confounding.

Results: Vegetables and fruit consumption was positively associated with psychological wellbeing (β=0.06, 95% CI 0.03, 0.10) but not depressive or anxiety symptoms, while SSB

consumption was associated with higher depressive (β=0.04, 95% CI 0.01, 0.06) and anxiety symptoms (β=0.02, 95% CI 0.00, 0.05), particularly in males, and lower psychological wellbeing (β=-0.03, 95% CI -0.05, -0.01).

Conclusion: Our results support the need to target SSB consumption as part of comprehensive mental health prevention and promotion interventions in adolescents.

Introduction

The mental health burden in adolescents (10–18 years old) is high, as evidenced by the high prevalence of common mental disorders[1] and the rates of emergency department visits and hospitalizations.[2,3] At present, there are no effective treatment options for mental disorders in this age group.[4] Considering the far-reaching ripple effects of unmanaged or poorly managed mental disorders further in life,[3] there is an urgent need for effective population-level prevention and promotion interventions to improve mental health in adolescents.

The role of lifestyle behaviours such as regular physical activity, limited screen time,[5] and good sleep[6] is well recognized. The evidence supporting the link between healthy eating and mental disorders is also accumulating.[7–10] Several systematic reviews of observational studies in adolescents support the associations of poor dietary intake and eating habits (e.g., eating take-away, ultraprocessed and fast foods) with negative mental health outcomes (e.g., depression and anxiety). The associations appeared more consistent in cross-sectional than prospective studies.[10–12] Importantly, the quality of existing cross-sectional studies was deemed fair at best,[11] and none of the prospective studies justified the included covariates. Often, these covariates included potential mediators (e.g., body mass index), adjustment for which might produce null-biased effect estimates of the total effect of diet on mental health (i.e., overadjustment bias). To circumvent the indiscriminate adjustment, we developed an evidence-based causal model, using the Evidence Synthesis for Constructing Directed Acyclic Graphs approach,[13] and identified and controlled for a set of confounders to estimate the association of diet and depressive and anxiety symptoms, and psychological wellbeing in a longitudinal study of Canadian adolescents.

Methods

Directed acyclic graph

Following the ESC-DAG approach,[13] we created a directed acyclic graph (DAG) which outlines our assumptions about causal relationships between variables relevant to the diet–mental health relationship, and identified the minimally sufficient adjustment set (more on DAGs is available elsewhere[14]). First, we identified seven prospective cohort studies[15–21] on the diet–mental health relationship in adolescents (i.e., 10–18 years old) as part of the ongoing systematic review (PROSPERO CRD42021246478). We did not consider cross-sectional studies given the uncertainty about temporal relationships between variables. Covariates adjusted for in prospective studies can be found in a confounder matrix (Appendix E). For each of these studies, we created an implied graph, which was then translated into a study-specific DAG by applying sequential causal criteria to and conducting a counterfactual thought experiment for each edge. Then, study-specific DAGs were combined into an integrated DAG by synthesizing all indexed directed edges using online *daggity* software.[22] To reduce the complexity and thereby increase the utility of the integrated DAG, we combined nodes that were conceptually related (e.g., family affluence and household income are both indicators of socioeconomic status [SES]) or had theoretical support to be considered as one node (e.g., physical activity, sedentary behaviour, sleep, and substance use were combined into the 'lifestyle behaviours' node). To verify each directed edge in the final DAG (Appendix F), we ran searches of peer-reviewed publications (preference given to randomized controlled trials or observational studies that explicitly focused on causal inference methods, if available) to justify inclusion vs. exclusion of each directed edge in the final DAG (Appendix G).

Importantly, while lifestyle behaviours (i.e., physical activity, sedentary behaviours, sleep, and substance use behaviours) did not qualify as confounders per d-separation rules, we considered them as competing exposures and therefore included them in the final minimally sufficient adjustment set comprised of: mental health at baseline, SES, age, eating behaviours, lifestyle behaviours, and social support (Table 3.1 for specific COMPASS variables mapped onto the DAG nodes). Finally, sex was omitted from the final DAG since we treated it as a potential effect modifier, which DAGs are not particularly suited to incorporate, and instead provide sex-stratified analyses for the final models.

Study design

Once the DAG was finalized, we accessed the Cannabis, Obesity, Mental health, Physical activity, Alcohol, Smoking, and Sedentary behaviour (COMPASS) data. COMPASS annually collects survey data from ~60,000 grade 9 to 12 high school students (13–18 years old) in British Columbia, Alberta and Ontario, and Secondary I-V students (12–17 years old) in Quebec, Canada (details available elsewhere[23]) using an active information passive-consent protocol (details available elsewhere[24]). Participants completed the paper-based, self-administered, anonymous COMPASS questionnaire during class time. For this study, we constructed a prospective cohort panel, using a sub-sample of participants surveyed in 2017/18 (baseline) and 2018/19 (one-year follow-up), whose responses were longitudinally-linked using an established deterministic linkage process (n=29,023).[25] Response proportions for 2017/18 and 2018/19 were 81.8% and 84.2%, respectively, with absenteeism during the survey administration being the primary reason for non-response. Analyses were limited to 13,887 participants from 116 schools with no missing data for variables included in the minimally sufficient adjustment set. Included

and excluded samples were similar, albeit smoking cigarettes and e-cigarettes was slightly more common in the excluded sample (Appendix H). COMPASS procedures were approved by the University of Waterloo Office of Research Ethics (#30118) and appropriate school board committees, and analyses presented in this study were approved by the Research Ethics Board at the University of Alberta (Pro00119528).

Measures

Depressive symptoms in the last seven days were measured by the CESD-R-10 scale,[26] generalized anxiety disorder symptoms in the last two weeks by the Generalized Anxiety Disorder 7 (GAD-7) scale,[27] and psychological wellbeing by the Flourishing Scale.[28] All scales have been validated in youth.[26,29,30] CESD-R-10 scores range from zero to 30 and GAD-7 from zero to 21, with higher scores indicating greater depressive and anxiety symptoms, respectively. CESD-R-10 and GAD-7 scores of 10 and higher indicate clinically relevant psychopathology. The Flourishing score ranges from eight to 40, with higher scores indicating better psychological wellbeing.

To assess healthy eating, participants reported the number of servings of vegetables and fruit that they consumed the day before, including pieces of fresh vegetable or fruit, salad or raw leafy greens, cooked leafy green vegetables, dried or canned or frozen fruit, and 100% fruit or vegetable juice. Participants also reported on their consumption of sugar-sweetened beverages (SSBs) as the number of days during a usual school week and weekend in which they consumed: 1) soft drinks (excluding diet/sugar-free drinks), 2) high-energy drinks (e.g., Red Bull, Monster, Rockstar), and 3) coffee or tea with sugar (e.g., cappuccino, frappuccino, iced tea, iced coffees).

Responses for these three categories were summed up to derive a composite index, ranging from zero (did not consume any SSBs in the three categories) to 21 (consumed SSBs from all three categories every day during a usual week).[31]

Participants reported their *sex* (female, male), *age* (years), and how much *weekly spending money* they usually get ($0, $1–5, $6–10, $11–20, $21–40, $41–100, >$100). Participants' responses were used to calculate the average number of: minutes of moderate (e.g., walking, biking to school, and recreational swimming) and vigorous (i.e., activities that increase heart rate) *physical activity* (MVPA) in the last seven days; minutes/day of *screen time* (i.e., watching/streaming TV shows or movies, playing video/computer games, talking on the phone, surfing the Internet, and texting, messaging, emailing); and hours/day of *sleep*. For substance use, participants reported the number of days in the last month they smoked one or more cigarettes (*tobacco smoking*) and e-cigarettes (*vaping*), and the past-12-month frequency of having five or more alcoholic drinks on one occasion *(binge drinking)* and using *cannabis*. Current users of cigarettes and e-cigarettes were those reporting smoking/vaping at least once in the past 30 days, and current cannabis users and binge drinkers were those reporting these behaviours at least once/month in the past year. Eating behaviours included *breakfast skipping* (i.e., negative responses to 'I eat breakfast every day') and *weight loss attempts* (i.e., positive responses to 'I'm trying to lose weight') as a proxy for dieting behaviours. To assess *social support*, participants were asked to indicate their level of agreement on a five-point scale with the statements: 'My social relationships are supportive and rewarding' (*supportive social relationships*) and 'I have a happy home life' (*happy family life*).

Additionally, the following variables were used in sensitivity analyses: self-reported *self-concept* (measured by the Self-Description Questionnaire II[32]), *perceived weight status* (underweight, healthy weight, overweight), *race*/*ethnicity* (white, Black, Asian, Hispanic, other/mixed), *academic achievement* (overall mark in a current/recent Math course: 90%-100%, 80%-89%, 70%-79%, 60%-69%, 55%-59%, 50%-54%, and <50%), and *geographic area* (Census metropolitan area, census agglomerations, small towns, and rural areas).

Statistical analyses

Descriptive statistics included means and standard deviations for normally distributed variables, and median and median absolute deviations (mad) otherwise. Responses ≥3 SDs outside the sample mean or in excess of 24 hours (for combined screen time and sleep) were considered outliers and winsorized. Although the intra-class correlation coefficients for all outcomes were <0.5,[33] mixed-effects models were chosen to account for the hierarchical data structure. Complete case analysis and fitted linear mixed-effects models (LMMs) with a random school intercept using maximum likelihood estimation were applied to the data to estimate the effects of vegetables and fruit and SSB consumption at baseline on depressive and anxiety symptoms and psychological wellbeing at one-year follow-up.

All covariates were measured at baseline and added sequentially to assess their incremental impact on effect estimates. Model 1 was adjusted for mental health at baseline; Model 2 additionally adjusted for sex, age, and weekly spending money; Model 3 additionally adjusted for breakfast skipping and weight loss attempts; Model 4 additionally adjusted for physical activity, screen time, sleep, tobacco smoking and vaping, binge drinking, and cannabis use; and

Model 5 additionally adjusted for supportive social relationships and happy family life. Akaike's information criteria (AIC) was used to assess the goodness-of-fit of each model. Final models were stratified by sex, given existing sex differences in diet and mental health. Cross-sectional analyses at baseline are reported in Appendix I. Analyses were performed using Stata 17 (College Station, TX).[34]

Sensitivity analyses

Sensitivity analyses for unmeasured confounding included estimating E-values[35] for regression coefficients reported in the final models, where 95% CI did not include the null, using the web-based E-value calculator.[36] We considered self-concept as a positive exposure control since it is causally linked to mental health problems in adolescence,[37] and the association between self-concept and mental health might be similarly confounded (e.g., by lifestyle behaviours, social support, baseline mental health). Lastly, to examine whether the addition of covariates not included in the minimally sufficient adjustment set impact effect estimates, we added self-perceived weight status, race/ethnicity, academic achievement, and geographic area to Model 5.

Results

Participants were, on average, 14.9 (SD=1.2) and 15.8 (SD=1.16) years old at baseline and one-year follow-up, respectively. Most participants were white (77.9%) and two-thirds lived in census metropolitan areas (66.3%) (Table 3.2). Over one-third of participants (43.1%) reported having ≥$21 in weekly spending money. Using the established cut-off of 10 for CESD-R-10 and GAD-7 scales, 32.4% and 22.7% of participants, respectively, were classified as having clinically significant depressive and anxiety symptoms; both were more common in females

(40.7% vs. 22.9% for depressive symptoms and 31.0% vs. 13.1% for anxiety symptoms). There were no sex-based differences in psychological wellbeing (median=32.0), vegetables and fruit (median=3.0) and SSB consumption (median=3.0). Males reported being physically active, on average, 17 minutes/day more (100.7 vs. 83.6 minutes/day of MVPA) and using screens ~15 minutes/day longer (6.0 vs. 5.8 hours/day) than females. Substance use was more common in males: 5.3% of males vs. 4.4% of females were classified as current smokers, 19.6% vs. 14.8% as current users of e-cigarettes, 12.2% vs. 11.1% as current binge-drinkers, and 7.9% vs. 6.7% as current users of cannabis. More females than males reported weight loss attempts (6.4% vs. 2.1%), and more males than females reported skipping breakfast (58.5% vs. 47.3%). Compared to females, males reported higher agreement with the statements that their social relationships were supportive (79.7% vs. 76.8% agreed or strongly agreed) and home life was happy (86.4% vs. 76.7% agreed or strongly agreed).

We observed no prospective association of vegetables and fruit consumption with the severity of depressive (β=0.03, 95% CI -0.02, 0.07) and anxiety symptoms (β=0.03, 95% CI -0.01, 0.07), whereas it was positively associated with psychological wellbeing (β=0.06, 95% CI 0.03, 0.10) (Table 3.3). SSB consumption was associated with higher depressive (β=0.04, 95% CI 0.01, 0.06) and anxiety symptoms (β=0.02, 95% CI 0.00, 0.05) and lower psychological wellbeing (β=-0.03, 95% CI -0.05, -0.01). The only product term that was deemed statistically significant was that of SSB consumption and sex; however, the effect estimates for males (β=0.07, 95% CI 0.03, 0.11) and females (β=0.01, 95% CI -0.03, 0.04) were not substantially different. Adjustment for mental health at baseline yielded the biggest reduction in AIC values and effect

estimates, with adjustment for other confounders moving effect estimates closer to the null (Appendix J).

Sensitivity analyses

All E-values for point estimates were higher than 1.06 (on the risk ratio scale; Table 3.4), suggesting that unmeasured confounder(s) would have to be relatively weak to nullify the associations. For example, an unmeasured confounder should be associated with both vegetables and fruit consumption and psychological wellbeing by a risk ratio of at least 1.11-fold to nullify the association and by at least 1.06-fold to shift the 95% CI to include the null. Also, the associations between self-concept and mental health outcomes remained strong, and effect estimates were considerably larger than those obtained for the exposures of interest. Finally, the addition of other covariates (i.e., self-perceived weight status, race/ethnicity, academic achievement, and geographic area) did not affect the estimates for any of the associations (Table 3.3).

Discussion

In this longitudinal study of 13,887 Canadian adolescents, we found a negative effect of SSB consumption on all mental health outcomes, as well as a positive effect of vegetables and fruit consumption on psychological wellbeing. No substantial sex differences were reported, in line with other prospective cohort studies.[15,18] All effect estimates were small, and sensitivity analyses showed that a relatively weak unknown and unmeasured confounder would be sufficient to nullify these effect estimates. Yet, small effect estimates do not mean that there is evidence of no effect.[35]

In fact, we argue that small effect estimates are to be expected for at least several reasons. First, mental health is impacted by a multitude of intertwined factors that act at multiple levels (individual, family, social). Second, it might take time for the effect of diet on mental health to accumulate and be observed. Hence, examining this relationship through the life-course epidemiology lens might yield important insights. Finally, diet often co-occurs with other behavioural factors that are causally related to mental health (e.g., tobacco smoking, binge drinking,[38] vaping,[39] cannabis use,[40] lack of physical activity, excess screen time,[5] and poor sleep[6]), and the combined effect of these lifestyle behaviours on mental health might compound in a synergistic fashion. This underscores the importance of developing and implementing comprehensive mental health prevention interventions that target *multiple* behaviours in adolescence, when common mental disorders often manifest for the first time[41] and when long-term health-related behaviours are being established.[42] Moreover, our findings should be viewed in the context of an alarmingly high prevalence of mental health problems and unhealthy lifestyle behaviours reported in this large population-based study of secondary school students. Based on established cut-offs, more than 30% and 20% of participants reported having clinically significant depressive and anxiety symptoms, respectively, with both being almost twice as common among females. Moreover, half of the participants reported consuming less than three servings of vegetables and fruit a day, four in five reported consuming at least one SSB drink on at least one day a week, one in five reported vaping in the past month, and almost one in ten reported binge drinking and cannabis use in the past year.

Our results suggest that these comprehensive mental health prevention interventions, specifically their dietary component, can benefit from reinforcing the importance of creating health-supporting environments to enable behavioural change. In Canada, an estimated 17.5% of free sugar originates from SSBs,[43] and given the enormous economic burden of free sugar consumption,[44] policy interventions, such as sugar taxation and other 'priority interventions' (e.g., product labelling, subsidies for healthful foods),[45] should be considered.

There are several methodological considerations. First, while drawing causal inferences from observational data is challenging, randomized controlled trials are neither ethical nor feasible to study the effect of diet on mental health, making high-quality prospective cohort studies the only avenue for causal inference in this field. Next, we acknowledge that our DAG for the diet–mental health relationship represents one of many possible data-generating processes, and we encourage researchers to develop other causal models while considering other potential confounders. For example, Molendijk et al.[8] previously highlighted chronic health conditions as a potentially important confounder; this might be the case in adults, but chronic health conditions are not common in adolescence and might not play such a prominent role in the etiology of mental disorders. Additionally, there may be important covariates at the parental level (e.g., parental mental health, eating habits, health literacy), but they would likely affect both diet and mental health through SES, and the latter has been adjusted for in our study.

Addressing measurement error, particularly associated with dietary intake, is a difficult task. Comprehensive dietary measures would help reduce the measurement error and allow us to consider other approaches to conceptualizing exposures (e.g., diet quality, dietary patterns).

Unfortunately, we did not locate any studies in Canada that collect comprehensive dietary and mental health data from middle adolescents. Moreover, weekly spending money and weight loss attempts are imperfect indicators of SES and dieting behaviours, respectively. Additionally, almost all measures were self-reported and therefore recall bias is possible, although it might have been partially negated by the anonymous nature of the COMPASS questionnaire. Given the large sample size, analyses could be overpowered; therefore, p-values did not guide interpretation of the results, as per current recommendations.[46]

Conclusion

Our results in a longitudinal study (COMPASS) with unique measures on a full range of lifestyle behaviours and mental health in middle adolescents showed that SSB consumption is consistently associated with higher severity of depressive and anxiety symptoms, as well as lower psychological wellbeing. This finding supports the need for targeting SSB consumption as part of comprehensive mental health prevention interventions.

Table 3.1. COMPASS variables mapped onto the nodes in the final DAG.

Variables included in the final DAG		**COMPASS variables**
Mental health at baseline and follow-up		Depressive symptoms (CESD-R-10 scale) Generalized anxiety disorder symptoms (GAD-7 scale) Psychological wellbeing (Flourishing scale)
Diet		Fruit and vegetables intake (number of servings consumed on the day before data collection) Sugar-sweetened beverages (number of days a week when participants consumed sugar-sweetened beverages, high-energy drinks, and coffee or tea with sugar)
Sex		Sex (females, males)
Age		Age (years)
Socio-economic status		Weekly spending money ($0, $1-5, $6-10, $11-20, $21-40, $41-100, >$100, and I don't know)
Eating behaviours	Breakfast skipping	Breakfast skipping
	Dieting	Weight loss attempts
Lifestyle behaviours	Physical activity	Moderate-to-vigorous physical activity (minutes/day)
	Screen time	Total screen time (hours/day) usually spent watching/streaming TV shows or movies, playing video/computer games, talking on the phone, surfing the internet, and texting, messaging, emailing
	Sleep	Sleep duration (hours/day)
	Tobacco smoking	Frequency of smoking cigarettes in the past 30 days (0, 1, 2-3, 4-5, 6-10, 11-20, 21-29, 30 days)
	Vaping	Frequency of smoking e-cigarettes in the past 30 days (0, 1, 2-3, 4-5, 6-10, 11-20, 21-29, 30 days)
	Alcohol consumption	Frequency of having 5 drinks of alcohol or more on one occasion in the past 12 months (never, on one occasion, less than once a month, once a month, 2-3 times a month, once a week, 2-5 times a week, and daily or almost daily)
	Drug use	Frequency of cannabis use in the past 12 months (never, not in the past 12 months, less than once a month, once a month, 2-3 times a month, once a week, 2-3 times/week, 4-6 times/week, and every day)
Social support		Having supportive and rewarding social relationships (strongly agree, agree, neither agree nor disagree, disagree, strongly disagree)
		Having a happy family life (strongly agree, agree, neither agree nor disagree, disagree, strongly disagree)

Table 3.2. Characteristics of 13,887 COMPASS participants at baseline (2017/18).

	Total	**Female**	**Male**
Depressive symptoms			
CES-D-R score, median (mad)	7.0 (4.4)	8.0 (5.9)	6.0 (4.4)
Yes (10 or higher), n (%)	4,504 (32.4)	3,028 (40.7)	1,476 (22.9)
Anxiety symptoms			
GAD-7 score, median (mad)	5.0 (4.4)	6.0 (5.9)	3.0 (4.4)
Yes (10 or higher), n (%)	3,157 (22.7)	2,311 (31.0)	846 (13.1)
Psychological wellbeing			
Flourishing score, median (mad)	32.0 (5.9)	32.0 (5.9)	33.0 (4.5)
Vegetables and fruit (servings/day), median (mad)	3.0 (1.5)	3.0 (1.5)	3.0 (1.5)
SSB (composite index), median (mad)	3.0 (2.9)	3.0 (2.9)	3.0 (2.9)
0	2,601 (18.7)	1,520 (20.4)	1,081 (16.8)
>0	11,286 (81.3)	5,928 (79.6)	5,358 (83.2)
Sex, n (%)	-	7,448 (54)	6,439 (46)
Age, mean (SD)	14.9 (1.2)	14.9 (1.2)	14.9 (1.1)
Weekly spending money, n (%)			
$0	3,049 (22.0)	1,473 (19.8)	1,576 (24.5)
$1 to $20	4,851 (34.9)	2,709 (36.3)	2,142 (33.3)
$21 to $100	3,775 (27.2)	2,132 (28.7)	1,643 (25.5)
more than $100	2,212 (15.9)	1,134 (15.2)	1,078 (16.7)
Weight loss attempt, n (%)	609 (4.4)	476 (6.4)	133 (2.1)
Breakfast skipping, n (%)	7,287 (52.5)	3,522 (47.3)	3,765 (58.5)
MVPA (minutes), median (mad⁎)	90.0 (66.7)	83.6 (60.4)	100.7 (73.1)
Screen time (hours/day), median (mad)	6.0 (3.3)	5.8 (3.3)	6.0 (3.3)
Sleep (hours/day), median (mad)	7.8 (1.1)	7.5 (1.1)	8.0 (1.5)
Current use of cigarettes, n (%)	672 (4.8)	330 (4.4)	342 (5.3)
Current use of e-cigarettes, n (%)	2,364 (17.0)	1,104 (14.8)	1,260 (19.6)
Current binge drinking, n (%)	1,611 (11.6)	827 (11.1)	784 (12.2)
Current cannabis use, n (%)	1,016 (7.3)	504 (6.7)	512 (7.9)
Supportive social relationships, n (%)			
(Strongly) agree	10,853 (78.1)	5,721 (76.8)	5,132 (79.7)
Neither/(Strongly) disagree	3,034 (21.9)	1,727 (23.2)	1,307 (20.3)
Happy home life, n (%)			
(Strongly) agree	11,173 (80.5)	5,711 (76.7)	5,562 (86.4)
Neither/(Strongly) disagree	2,714 (19.5)	1,737 (23.3)	887 (13.6)
Variables used in sensitivity analyses			
Self-concept score, mean (sd)	10.0 (4.4)	11.0 (4.4)	9.0 (4.4)
Self-perceived weight status, n (%)			
Underweight	2,222 (16.0)	821 (11.0)	1,401 (21.8)
About right	8,427 (60.7)	4,714 (63.3)	3,713 (57.7)
Overweight	3,238 (23.3)	1,913 (25.7)	1,325 (20.6)
Race/ethnicity, n (%)⁑			

White	10,818 (77.9)	5,837 (78.4)	4,981 (77.4)
Black	526 (3.8)	261 (3.5)	265 (4.1)
Asian	1,911 (13.8)	1,040 (14.0)	871 (13.5)
Hispanic	467 (3.4)	250 (3.4)	217 (3.4)
Other/Mixed	1,406 (10.1)	805 (10.8)	601 (9.3)
Overall mark in a current/recent Math course, n (%)			
90-100%	3,664 (26.4)	2,097 (28.2)	1,567 (24.3)
80-89%	4,072 (29.3)	2,222 (29.8)	1,850 (28.7)
70-79%	3,077 (22.2)	1,584 (21.3)	1,493 (23.2)
60-69%	1,739 (12.5)	883 (11.9)	856 (13.3)
<60%	1,335 (9.6)	662 (8.8)	673 (10.5)
Geographic area†, n (%)			
Census metropolitan areas	9,306 (67.0)	5,042 (67.7)	4,264 (66.2)
Census agglomerations	1,914 (13.8)	1,008 (13.5)	906 (14.1)
Small towns and rural areas	2,667 (19.2)	1,398 (18.8)	1,269 (19.7)

‡ proportions do not add up since participants could choose multiple ethnicities

⁎ mad: median absolute deviation

† Geographic area was classified according to population into census metropolitan areas (>100,000 population), census agglomerations (10,000 to 100,000), and small towns and rural areas (<10,000).

Table 3.3. Prospective associations between fruit and vegetables intake, SSB consumption, self-concept (i.e., positive exposure control) at baseline and depressive and anxiety symptoms, and psychological wellbeing at 1-year follow-up in COMPASS study (2017/18 to 2018/19).

	Unadjusted	**Model 1***	**Model 2**	**Model 3**	**Model 4**	**Model 5**			**Sensitivity analyses**	
						Total	**Females**	**Males**	**Model 6**	**Model 7**
	β (95% CI)	**β (95% CI)**	**β (95% CI)**	**β (95% CI)**	**β (95% CI)**	**β (95% CI)**	**β (95% CI)**	**β (95% CI)**	**β (95% CI)**	**β (95% CI)**
Depressive symptoms										
Exposure of interest										
VF	**-0.24 (-0.29, -0.19)**	**-0.05 (-0.09, -0.01)**	**-0.05 (-0.09, -0.01)**	-0.02 (-0.07, 0.02)	0.01 (-0.03, 0.05)	0.03 (-0.02, 0.07)	0.06 (-0.00, 0.12)	-0.01 (-0.07, 0.05)	0.03 (-0.01, 0.07)	0.03 (-0.01, 0.07)
SSB	**0.17 (0.14, 0.20)**	**0.04 (0.02, 0.07)**	**0.06 (0.04, 0.09)**	**0.05 (0.03, 0.08)**	**0.04 (0.01, 0.06)**	**0.04 (0.01, 0.06)**	0.01 (-0.03, 0.04)	**0.07 (0.03, 0.11)**	**0.04 (0.01, 0.06)**	**0.04 (0.01, 0.06)**
Positive exposure control										
Self-concept	**0.68 (0.66, 0.70)**	**0.25 (0.23, 0.27)**	**0.24 (0.21, 0.26)**	**0.22 (0.20, 0.25)**	**0.22 (0.19, 0.24)**	**0.19 (0.17, 0.22)**	**0.20 (0.17, 0.23)**	**0.18 (0.15, 0.21)**	**0.19 (0.16, 0.21)**	**0.19 (0.16, 0.21)**
Anxiety symptoms										
Exposure of interest										
VF	**-0.12 (-0.17, -0.07)**	-0.02 (-0.06, 0.02)	-0.01 (-0.05, 0.02)	0.01 (-0.03, 0.04)	0.02 (-0.02, 0.06)	0.03 (-0.01, 0.07)	**0.06 (0.00, 0.11)**	0.01 (-0.04, 0.06)	0.03 (0.00, 0.07)	0.04 (0.00, 0.07)
SSB	**0.15 (0.12, 0.17)**	**0.02 (0.00, 0.05)**	**0.05 (0.02, 0.07)**	**0.04 (0.02, 0.06)**	**0.03 (0.00, 0.05)**	**0.02 (0.00, 0.05)**	-0.01 (-0.04, 0.03)	**0.06 (0.02, 0.09)**	**0.02 (0.00, 0.05)**	**0.02 (0.00, 0.05)**
Positive exposure control										
Self-concept	**0.53 (0.52, 0.55)**	**0.16 (0.14, 0.18)**	**0.15 (0.13, 0.17)**	**0.14 (0.12, 0.16)**	**0.13 (0.11, 0.15)**	**0.12 (0.10, 0.15)**	**0.12 (0.09, 0.14)**	**0.13 (0.10, 0.16)**	**0.12 (0.10, 0.14)**	**0.12 (0.10, 0.14)**
Psychological wellbeing										
Exposure of interest										
VF	**0.45 (0.41, 0.50)**	**0.11 (0.07, 0.14)**	**0.10 (0.06, 0.14)**	**0.09 (0.05, 0.13)**	**0.06 (0.03, 0.10)**	**0.06 (0.03, 0.10)**	**0.07 (0.02, 0.12)**	**0.06 (0.00, 0.11)**	**0.06 (0.02, 0.10)**	**0.06 (0.02, 0.10)**
SSB	**-0.11 (-0.14, -0.08)**	**-0.03 (-0.05, 0.00)**	**-0.04 (-0.06, -0.02)**	**-0.04 (-0.06, -0.01)**	**-0.03 (-0.05, -0.01)**	**-0.03 (-0.06, -0.01)**	**-0.03 (-0.06, 0.00)**	**-0.03 (-0.06, -0.00)**	**-0.03 (-0.05, -0.01)**	**-0.03 (-0.05, -0.01)**
Positive exposure control										
Self-concept	**-0.70 (-0.71, -0.68)**	**-0.23 (-0.26, -0.21)**	**-0.23 (-0.25, -0.21)**	**-0.23 (-0.25, -0.20)**	**-0.22 (-0.25, -0.20)**	**-0.21 (-0.23, -0.18)**	**-0.21 (-0.24, -0.18)**	**-0.20 (-0.23, -0.17)**	**-0.21 (-0.23, -0.18)**	**-0.20 (-0.23, -0.18)**

β: unstandardized beta-coefficients from linear mixed-effects models; 95% CI: 95% confidence interval; SSB: sugar-sweetened beverages, composite index; VF: vegetables and fruit consumption.

*Model 1 adjusted for depressive and anxiety symptoms at baseline (as appropriate); Model 2 – additionally adjusted for weekly spending money, age, sex; Model 3 – additionally adjusted for breakfast skipping, weight loss attempts; Model 4 – additionally adjusted for physical activity, screen time, sleep, smoking cigarettes and e-cigarettes, binge-drinking, cannabis use; Model 5 – additionally adjusted for so supportive social relationships and happy family life; Model 6 – additionally adjusted for self-perceived weight status; and Model 7 – additionally adjusted for race/ethnicity, geographic location, and math score.

Table 3.4. E-values for point estimates and confidence intervals for the prospective associations between the exposures of interest (i.e., fruit and vegetables intake, sugar-sweetened beverages intake) and the outcomes of interest (i.e., depressive and anxiety symptoms, psychological wellbeing) in the COMPASS study (2017/18 to 2018/19).

	Model 5				**E-values† for:**	
	β	**SE**	**95% CI**		**point estimate**	**CI**
			LL	**UL**		
Depressive symptoms						
SSB	0.04	0.01	0.01	0.06	1.08	1.06
Anxiety symptoms						
SSB	0.02	0.01	0.00	0.05	1.06	1.01
Psychological wellbeing						
Vegetables and fruit	0.06	0.02	0.03	0.10	1.11	1.06
SSB	-0.03	0.01	-0.05	-0.01	1.08	1.04

β: unstandardized beta-coefficients from linear mixed-effects models; SSB: sugar-sweetened beverages (days/week); SE: standard error; 95% CI: 95% confidence interval; LL: lower limit; UL: upper limit.
†To calculate E-values, the following standard deviations for the outcomes of interest were used: 6.01 for the CESD-R-10 score, 5.55 for the GAD7 score, and 5.49 for the Flourishing score at 1-year follow-up. E-values are reported on the risk ratio scale.

References

1. Wiens K, Williams JVA, Lavorato DH, et al. Is the prevalence of major depression increasing in the Canadian adolescent population? Assessing trends from 2000 to 2014. *J Affect Disord*. 2017;210:22–6.
2. Canadian Institute for Health Information. *Care for children and youth with mental disorders.* 2015. https://secure.cihi.ca/free_products/CIHI%20CYMH%20Final%20for%20pubs_EN_web.pdf
3. Gardner W, Pajer K, Cloutier P, et al. Changing rates of self-harm and mental disorders by sex in youths presenting to Ontario emergency departments: repeated cross-sectional study. *Can J Psychiatry*. 2019;64(11):789–97.
4. Cipriani A, Zhou X, Del Giovane C, et al. Comparative efficacy and tolerability of antidepressants for major depressive disorder in children and adolescents: a network meta-analysis. *Lancet*. 2016;388(10047):881–90.
5. Asare M. Sedentary behaviour and mental health in children and adolescents: a meta-analysis. *J Child Adolesc Behav*. 2015;3:259.
6. Lovato N, Gradisar M. A meta-analysis and model of the relationship between sleep and depression in adolescents: recommendations for future research and clinical practice. *Sleep Med Rev*. 2014;18(6):521–9.
7. Afshin A, Sur PJ, Fay KA, et al. Health effects of dietary risks in 195 countries, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet*. 2019;393(10184):1958–72.
8. Molendijk M, Molero P, Ortuno Sanchez-Pedreno F, Van der Does W, Angel Martinez-Gonzalez M. Diet quality and depression risk: a systematic review and dose-response meta-analysis of prospective studies. *J Affect Disord*. 2018;226:346–54.
9. Hayward J, Jacka FN, Skouteris H, et al. Lifestyle factors and adolescent depressive symptomatology: associations and effect sizes of diet, physical activity and sedentary behaviour. *Aust N Z J Psychiatry*. 2016;50(11):1064–73.
10. O'Neil A, Quirk SE, Housden S, et al. Relationship between diet and mental health in children and adolescents: a systematic review. *Am J Public Health*. 2014;104(10):e31–42.
11. Khalid S, Williams CM, Reynolds SA. Is there an association between diet and depression in children and adolescents? A systematic review. *Br J Nutr*. 2016;116(12):2097–108.
12. Orlando L, Savel KA, Madigan S, Colasanto M, Korczak DJ. Dietary patterns and internalizing symptoms in children and adolescents: a meta-analysis. *Aust N Z J Psychiatry*. 2022;56(6):617-641.
13. Ferguson KD, McCann M, Katikireddi SV, et al. Evidence synthesis for constructing directed acyclic graphs (ESC-DAGs): a novel and systematic method for building directed acyclic graphs. *Int J Epidemiol*. 2020:49(1):322-9.
14. Tennant PWG, Murray EJ, Arnold KF, et al. Use of directed acyclic graphs (DAGs) to identify confounders in applied health research: review and recommendations. *Int J Epidemiol*. 2021;50(2):620–32.
15. Esteban-Gonzalo L, Turner AI, Torres SJ, et al. Diet quality and well-being in children and adolescents: the UP&DOWN longitudinal study. *Br J Nutr*. 2019;121(2):221–31.
16. McMartin SE, Kuhle S, Colman I, Kirk SF, Veugelers PJ. Diet quality and mental health in subsequent years among Canadian youth. *Public Health Nutr*. 2012;15(12):2253–8.

17. Wilson J, Blizzard L, Gall S, et al. Youth diet quality and hazard of mood disorder in adolescence and adulthood among an Australian cohort. *J Affect Disord*. 2020;276:511-8.
18. Winpenny EM, van Harmelen AL, White M, van Sluijs EMF, Goodyer IM. Diet quality and depressive symptoms in adolescence: no cross-sectional or prospective associations following adjustment for covariates. *Public Health Nutr*. 2018;21(13):2376–84.
19. Wu X, Bastian K, Ohinmaa A, Veugelers P. Influence of physical activity, sedentary behavior, and diet quality in childhood on the incidence of internalizing and externalizing disorders during adolescence: a population-based cohort study. *Ann Epidemiol*. 2018;28(2):86–94.
20. Jacka FN, Rothon C, Taylor S, Berk M, Stansfeld SA. Diet quality and mental health problems in adolescents from East London: a prospective study. *Soc Psychiatry Psychiatr Epidemiol*. 2013;48(8):1297–306.
21. Jacka FN, Kremer PJ, Berk M, et al. A prospective study of diet quality and mental health in adolescents. *PloS One*. 2011;6(9):e24805.
22. Textor J, van der Zander B, Gilthorpe MS, Liskiewicz M, Ellison GT. Robust causal inference using directed acyclic graphs: the R package "dagitty." *Int J Epidemiol*. 2016;45(6):1887–94.
23. 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):1-7.
24. Thompson-Haile A, Bredin C, Leatherdale ST. Rationale for using an active information passive-consent permission protocol. Waterloo: University of Waterloo; COMPASS Technical Report Series, vol.1, 2013. https://uwaterloo.ca/compass-system/publications/rationale-using-active-information-passive-consent
25. Methods for linking COMPASS student-level data over time. COMPASS System. 2015. https://uwaterloo.ca/compass-system/publications/methods-linking-compass-student-level-data-over-time
26. Bradley KL, Bagnell AL, Brannen CL. Factorial validity of the Center for Epidemiological Studies Depression 10 in adolescents. *Issues Ment Health Nurs*. 2010;31(6):408–12.
27. Spitzer RL, Kroenke K, Williams JBW, Löwe B. A brief measure for assessing generalized anxiety disorder: the GAD-7. *Arch Intern Med*. 2006;166(10):1092–7.
28. Diener E, Wirtz D, Tov W, et al. New well-being measures: short scales to assess flourishing and positive and negative feelings. *Soc Indic Res*. 2010;97(2):143–56.
29. Tiirikainen K, Haravuori H, Ranta K, Kaltiala-Heino R, Marttunen M. Psychometric properties of the 7-item Generalized Anxiety Disorder Scale (GAD-7) in a large representative sample of Finnish adolescents. *Psychiatry Res*. 2019;272:30–5.
30. Romano I, Ferro MA, Patte KA, Diener E, Leatherdale ST. Measurement invariance of the flourishing scale among a large sample of Canadian adolescents. *Int J Environ Res Public Health*. 2020;17(21):7800.
31. Godin KM, Chaurasia A, Hammond D, Leatherdale ST. Food purchasing behaviors and sugar-sweetened beverage consumption among Canadian secondary school students in the COMPASS Study. *J Nutr Educ Behav*. 2018;50(8):803-12.
32. Marsh HW. SDQ II manual: self description questionnaire - II. Campbelltown, N.S.W.: University of Western Sydney, Macarthur; 1990.

33. Hox J. Multilevel analysis: techniques and applications (Reprint. ed.) Erlbaum. Mahwah, NJ: Erlbaum; 2002.
34. StataCorp. Stata Statistical Software: Release 17. College Station, TX: StataCorp LLC; 2021.
35. VanderWeele TJ, Ding P. Sensitivity analysis in observational research: introducing the E-value. *Ann Intern Med*. 2017;167(4):268–74.
36. Mathur MB, Ding P, Riddell CA, VanderWeele TJ. Web Site and R Package for Computing E-values. *Epidemiology*. 2018;29(5):e45–7.
37. Busch J, Claus C, Schneider S, Siefen RG. Does a lower self-concept contribute to mental health disparities of diverse immigrant youth from middle childhood to late adolescence? *BMC Psychol*. 2021;9(1):1–14.
38. Cairns KE, Yap MBH, Pilkington PD, Jorm AF. Risk and protective factors for depression that adolescents can modify: a systematic review and meta-analysis of longitudinal studies. *J Affect Disord.* 2014;169(h3v):61–75.
39. Becker TD, Arnold MK, Ro V, Martin L, Rice TR. Systematic review of electronic cigarette use (vaping) and mental health comorbidity among adolescents and young adults. *Nicotine Tob Res*. 2021;23(3):415–25.
40. Gobbi G, Atkin T, Zytynski T, et al. Association of cannabis use in adolescence and risk of depression, anxiety, and suicidality in young adulthood. A systematic review and meta-analysis. *JAMA Psychiat*. 2019;76(4):426–34.
41. Kessler RC, Berglund P, Demler O, Jin R, Merikangas KR, Walters EE. Lifetime prevalence and age-of-onset distributions of DSM-IV disorders in the National Comorbidity Survey Replication. *Arch Gen Psychiatry*. 2005;62(6):593–602.
42. Viner RM, Ross D, Hardy R, Kuh D, Power C, Johnson A, et al. Life course epidemiology: recognising the importance of adolescence. *J Epidemiol Community Health*. 2015;69(8):719–20.
43. Statistics Canada. Added, free and total sugar content and consumption of foods and beverages in Canada. 2020. https://www150.statcan.gc.ca/n1/pub/82-003-x/2020010/article/00002-eng.htm
44. Liu S, Munasinghe LL, Maximova K, Taylor JP, Ohinmaa A, Veugelers PJ. The economic burden of excessive sugar consumption in Canada: should the scope of preventive action be broadened? *Can J Public Health*. 2022;113(3):331–40.
45. Veugelers PJ, Taylor JP, Ohinmaa A, Liu S, Munasinghe LL, Maximova K. To tax or not to tax? That's the sugar-coated question. *Can J Public Health*. 2022;113(5):786-7.
46. Wasserstein RL, Schirm AL, Lazar NA. Moving to a world beyond "p<0.05." *Am Stat*. 2019;73(sup1):1–19.

Chapter 4: Temporal changes in the consumption of vegetables and fruit and sugar-sweetened beverages, and their impact on depression and anxiety among adolescents: a longitudinal analysis of COMPASS

Dabravolskaj J, Yamamoto S, Patte KA, Leatherdale ST, Veugelers PJ, Maximova K. Temporal changes in the consumption of vegetables and fruit and sugar-sweetened beverages, and their impact on depression and anxiety among adolescents: A longitudinal analysis of COMPASS data. [to be submitted]

Abstract

Background: Evidence on the importance of diet for mental health is emerging at a time when burden of mental disorders is on the rise. Whereas the objective of many health promotion and chronic diseases prevention campaigns is to increase consumption of vegetables & fruit (VF) and reduce that of sugar-sweetened beverages (SSB), no earlier study reported on the impact of changes in the consumption of VF and SSB on mental health. We examined this among Canadian adolescents (14–17-year-olds).

Methods: Diet and mental health were assessed annually in 2016/17, 2017/18 and 2018/19 (mean age 14.5, 15.5 and 16.5, respectively) through school-based surveys of 5,653 students from 68 Canadian schools who participated in the Cannabis, Obesity, Mental health, Physical activity, Alcohol, Smoking, and Sedentary behaviour (COMPASS) study. Estimates of initial levels and rates of change in VF and SSB consumption were derived from individual growth models and included in linear mixed-effects models of depressive and anxiety symptoms (measured by CESD-R-10 and GAD-7 scales, respectively) in 2018/19, adjusted for baseline depressive and anxiety symptoms, age, sex, and other individual- and area-level confounders.

Results: VF and SSB consumption deteriorated between 2016/17 and 2018/19. In females, the change of one serving/year in VF consumption and one point/year in SSB composite index was associated with 0.23-point lower and 0.12-point higher CESD-R-10 scores, respectively. These associations were weaker in males. No associations with GAD-7 scores were evident.

Conclusion: Adolescent diets deteriorate during mid-adolescence, and these changes are associated with greater severity of depressive symptoms (but not anxiety symptoms). Results call for population-level prevention approaches to counteract the downward changes in diet during adolescence to reduce the growing mental health burden in addition to reducing the chronic disease burden.

Introduction

The burden of mental disorders in adolescents has been high and on the rise even before the COVID-19 pandemic: between 2011 and 2018, the prevalence of self-reported mood and anxiety disorders diagnoses among Canadian adolescents increased from 4% to 8% and from 6% to 13%, respectively.[1] The pandemic further accelerated this negative trend towards worse mental health by adding many stressors that impacted adolescents' mental health and well-being.[2] A recent meta-analysis of 29 studies showed the estimated global prevalence of elevated depression and anxiety symptoms in adolescents in the first year of the COVID-19 pandemic to be 21%,[3] which are approximately double the pre-pandemic levels, with female adolescents being at a particularly high risk.

Recent systematic reviews[4,5] provide support for the role of poor diet in the development of mental disorders in adolescents. However, to understand this relationship better, we need to take into account a plethora of changes to lifestyle behaviours that occur during adolescence. This developmental transition from childhood to adulthood is characterized by rapid shifts toward an unhealthy diet,[6] and these changes may in turn be relevant to the development of mental health issues.[7,8] Additionally, other unhealthy lifestyle behaviours (e.g., binge drinking, tobacco smoking, vaping, and drug use) also become more common as adolescents gain greater independence in lifestyle choices, notably around the age of 14,[9–11] and may have consequences for adolescent mental health.

Extant prospective studies on this focal relationship tend to consider dietary consumption at one point only,[12–18] despite diet being multidimensional and dynamic, particularly during

adolescence.[8] There is a need to conceptualize changes in dietary consumption over time (or dietary trajectories) using repeated measurements and consider the impact of these changes on mental health in adolescence. In the current study, we examined the association between changes in dietary consumption of vegetables & fruit (VF) and sugar-sweetened beverages (SSB) between 14.5 and 16.5 years, with the severity of depressive and anxiety symptoms at 16.5 years of age in a large sample of Canadian middle adolescents, while adjusting for a comprehensive set of relevant confounders.

Methods

Study design

The Cannabis, Obesity, Mental health, Physical activity, Alcohol, Smoking, and Sedentary behaviour (COMPASS) study annually conducts school-based surveys of approximately 60,000 grade 9 to 12 high school students (13–18 years old) in British Columbia, Alberta and Ontario, and Secondary I–V students (12–17 years old) in Quebec, Canada (details available elsewhere[19]). Participants complete the paper-based, self-administered COMPASS questionnaire during class time.

For this study, we constructed a prospective cohort panel using a sub-sample of participants surveyed in 2016/17 (response rate [RR] 77.5%), 2017/18 (RR 81.8%), and 2018/19 (RR 84.2%), whose responses were linked using an established deterministic linkage process.[20] The complete case analyses were conducted in a sub-sample of 5,653 participants from 68 schools. COMPASS procedures were approved by the University of Waterloo Office of Research Ethics

(#30118) and appropriate school board committees, and analyses presented in this study were approved by the Research Ethics Board at the University of Alberta (Pro00119528).

Measures

Depressive symptoms in the last seven days were measured by the CESD-R-10 scale,[21] and generalized anxiety disorder symptoms in the previous two weeks by the Generalized Anxiety Disorder 7 (GAD-7) scale.[22] CESD-R-10 scores range from 0 to 30 and GAD-7 from 0 to 21, with higher scores in both scales indicating greater severity of depressive and anxiety symptoms, respectively. Both scales have been validated in adolescents.[21,23]

Participants reported the number of servings of VF they consumed the day before, including pieces of fresh vegetable or fruit, salad or raw leafy greens, cooked leafy green vegetables, dried or canned or frozen fruit, and 100% fruit or vegetable juice. Participants also reported their consumption of SSB as the number of days during a usual school week and weekend in which they consumed: 1) soft drinks (excluding diet/sugar-free drinks), 2) high-energy drinks (e.g., Red Bull, Monster, Rockstar, etc.), and 3) coffee or tea with sugar (e.g., cappuccino, frappuccino, iced tea, iced coffees). A composite index, ranging from 0 (did not consume any SSB in the three categories) to 21 (consumed SSB from all three categories every day during a usual week), was derived by summing up responses for these three categories.[24]

Participants reported their sex (female or male), age (years), and race/ethnicity (white, Black, Asian, Hispanic, other/mixed). The quintile of neighbourhood's material deprivation (with 1 being the least and 5 being the most materially deprived neighbourhoods) was derived from

school postal codes[25] and included in analyses as an indicator of area-level socioeconomic status. Participants reported several lifestyle behaviours: a daily average of minutes of moderate (e.g., walking, biking to school, and recreational swimming) and vigorous (e.g., jogging, team sports, fast dancing, jump-rope, and any other physical activities that increase your heart rate and make you breathe hard and sweat) physical activity (MVPA) they engaged in for each of the last seven days; minutes/day of screen time (watching/streaming TV shows or movies, playing video/computer games, talking on the phone, surfing the Internet, and texting, messaging, emailing); hours/day of sleep; current use of cigarettes and e-cigarettes, defined as using these substances at least once in the past 30 days; current use of cannabis and binge drinking (5 or more alcoholic drinks on one occasion), defined as using these substances at least once/month in the past 12 months. Eating behaviours included breakfast skipping (negative responses to "I eat breakfast every day") and weight loss attempts (positive responses to "I am trying to lose weight") as a proxy for dieting behaviours. Finally, participants rated their social and family relationships using a 5-point scale: "My social relationships are supportive and rewarding" (responses "agree" and "strongly agree" indicated supportive social relationships) and "I have a happy home life" (responses "agree" and "strongly agree" indicated happy family life).

Statistical analysis

Descriptive statistics included count (%) for categorical variables and means (standard deviations) and medians (median absolute deviations) for normally and not normally distributed continuous variables, respectively. Responses ≥3 SDs outside the sample mean of continuous covariates were considered outliers and winsorized (i.e., replaced with closest values within 3 SDs).

Individual growth models were applied to repeat observations of dietary consumption for each participant at three timepoints (2016/17, 2017/18, 2018/19), with student's age representing time. Age was centered around the mean age in 2016/17 (14.5 years) to facilitate the interpretation of intercept as an estimate of dietary consumption at age 14.5 years rather than zero. For each participant, two estimates were derived from individual growth models of VF and SSB consumption: initial level (intercept) and rate of change (slope). These estimates were then used in linear mixed-effects models to assess their associations with the severity of depressive and anxiety symptoms in 2018/19 (mean age 16.5). Separate models were conducted for depressive and anxiety symptoms. Model 1 adjusted for mental health at baseline, Model 2 – additionally adjusted for quintile of neighbourhood material deprivation, age and sex, Model 3 – additionally adjusted for breakfast skipping and weight loss attempts, Model 4 – additionally adjusted for physical activity, screen time, sleep, tobacco smoking and vaping, binge drinking, cannabis use, and Model 5 – additionally adjusted for supportive social relationships and happy family life. The consideration of confounders in the study of diet and mental health is a current topic of debate.[4,26] The list of confounders adjusted in our analyses is the outcome of a systematic approach process which we described in detail elsewhere[27] (see Chapter 3). All confounders were measured in 2017/18, one year prior to depressive and anxiety symptoms. The results from the final models are reported separately for females and males to reveal potential sex-based differences. Analyses were performed using Stata 17 (College Station, TX).[28]

Results

Among 5,653 participants included in this study, there were more females than males (55.9% vs. 44.1%) (see Table 4.1). Females scored higher on both mental health scales than males: 9.59 vs.

7.21 on CESD-R-10 and 7.83 vs. 4.64 on GAD-7. Compared to females, males reported consuming slightly more VF servings/day (3.07 vs. 2.99) and SSBs (4.07 vs. 3.77, as captured by the composite index). Weight loss attempts were considerably more common among females (6.4% vs. 2.2%). Substance use behaviours (e.g., smoking, vaping, cannabis use) were more common among males. Males also reported being more physically active, engaging on average in 20 minutes/day more MVPA than females.

Table 4.1. Characteristics of study participants at baseline (2017/18), according to student's sex (n=5,653).

	Total	**Female**	**Male**
Depressive symptoms			
CESD-R-10 score, median (mad[4])	7.0 (5.9)	8.0 (5.9)	6.0 (4.5)
Anxiety symptoms			
GAD-7 score, median (mad)	5.0 (5.9)	7.0 (5.9)	3.0 (4.5)
Vegetables and fruit (servings/day), median (mad)	3.0 (1.5)	3.0 (1.5)	3.0 (2.9)
SSB consumption (composite index), median (mad)	3.0 (2.9)	3.0 (2.9)	3.0 (2.9)
0	1,066 (18.9)	646 (20.4)	420 (16.9)
>0	4,587 (81.1)	2,514 (79.6)	2,073 (83.1)
Sex, n (%)	-	3,160 (55.9)	2,493 (44.1)
Age, mean (SD)	15.5 (0.9)	15.5 (0.9)	15.5 (0.9)
Quintile of material deprivation (school-area SES), n (%)			
1	839 (14.8)	500 (15.8)	339 (13.6)
2	1,699 (30.1)	956 (30.2)	743 (29.8)
3	863 (15.3)	482 (15.3)	381 (15.3)
4	1,627 (28.8)	881 (27.9)	746 (29.9)
5	625 (11.1)	341 (10.8)	284 (11.4)
Weight loss attempt, n (%)	256 (4.5)	202 (6.4)	54 (2.2)
Breakfast skipping, n (%)	2,725 (48.2)	1,381 (43.7)	1,344 (53.9)
MVPA (minutes/day), median (mad)	92.1 (69.9)	85.7 (63.5)	105.0 (76.3)
Screen time (hours/day), median (mad)	6.0 (3.7)	6.0 (3.7)	6.5 (3.7)
Sleep (hours/day), median (mad)	7.3 (1.1)	7.0 (1.5)	7.5 (0.7)
Current use of cigarettes•, n (%)	307 (5.4)	153 (4.8)	154 (6.2)
Current use of e-cigarettes•, n (%)	953 (16.9)	444 (14.1)	509 (20.4)

Current binge drinking⁑, n (%)	1,802 (31.9)	1,007 (31.9)	795 (31.9)
Current cannabis use†, n (%)	1,043 (18.5)	558 (17.7)	485 (19.5)
Supportive social relationships, n (%)			
(Strongly) agree	4,418 (78.2)	2,434 (77.0)	1,984 (79.6)
Neither/(Strongly) disagree	1,235 (21.9)	726 (22.9)	509 (20.4)
Happy home life, n (%)			
(Strongly) agree	4,597 (81.3)	2,440 (77.5)	2,148 (86.2)
Neither/(Strongly) disagree	1,056 (18.7)	711 (22.5)	345 (13.8)
Other variables			
Race/ethnicity, n (%)⁂			
White	4,536 (80.2)	2,579 (81.6)	1,957 (78.5)
Black	247 (4.4)	134 (4.2)	113 (4.5)
Asian	563 (10.0)	319 (10.1)	244 (9.8)
Hispanic	221 (3.9)	110 (3.5)	111 (4.5)
Other/Mixed	638 (11.3)	347 (11.0)	291 (11.7)

⁄ mad: median absolute deviation.
• Current use of cigarettes and e-cigarettes is defined as use on at least one day in the past 30 days.
⁑ Current binge drinking is defined as having five or more drinks on one occasion less than once a month or more often in the past 12 months.
† Current cannabis use is defined as consuming cannabis at least once a month in the past 12 months.

We observed a decline in the average VF consumption and an increase in the average SSB consumption between 2016/17 and 2018/19, and these trends were observed in the total sample and separately among females and males (Figure 4.1). Females and males reported consuming on average 0.3 and 0.2 fewer servings of VF in 2018/19, respectively, compared to 2016/17. During the same time period, SSB consumption increased more among males than females (0.4 and 0.3, respectively). Sex-based differences in the changes in VF and SSB consumption over time were confirmed using multi-level growth curve models (Appendix K).

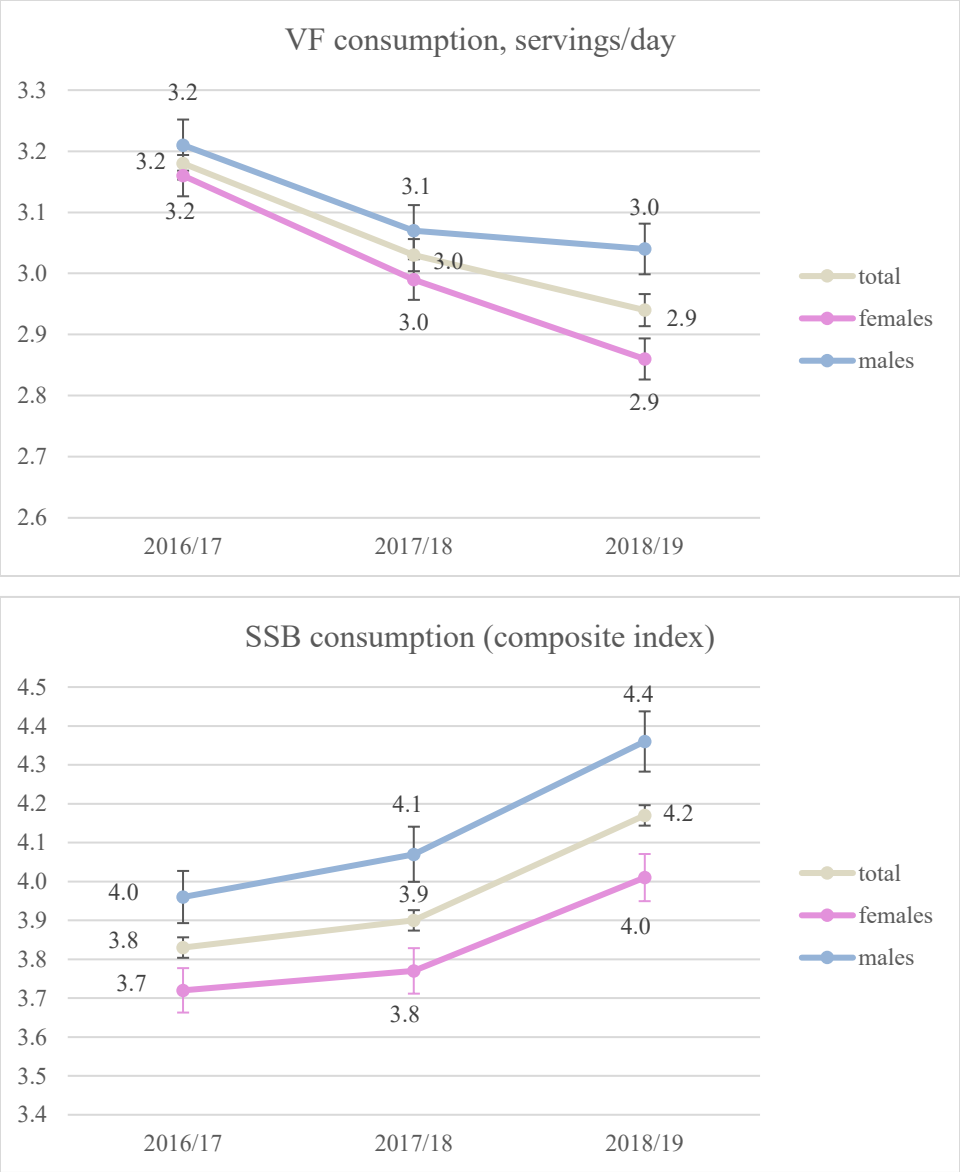


Figure 4.1. Average consumption of VF and SSB in three consecutive years among adolescents (14–17-year-old).

Table 4.2. Sex as the predictor of the initial level and rate of change in VF and SSB consumption using multilevel linear growth curve models.

Dependent variable	Coefficient	Standard error	p-value
Vegetables & fruit consumption			
Fixed effect			
Intercept	**3.169**	**0.034**	**<0.001**

Age	**-0.215**	**0.036**	**<0.001**
Male	0.052	0.051	0.305
Male*age	**0.057**	**0.024**	**0.015**
Random effects			
Variance (intercept)	2.070	0.065	NP
Variance (time)	0.040	0.017	NP
Covariance (intercept, time)	-0.065	0.025	NP
Residual variance	1.854	0.030	NP
SSB consumption			
Fixed effect			
Intercept	**3.615**	**0.055**	**<0.001**
Age	**0.154**	**0.062**	**0.013**
Male	**0.243**	**0.084**	**0.004**
Male*age	0.045	0.040	0.272
Random effects			
Variance (intercept)	5.738	0.184	NP
Variance (time)	0.287	0.051	NP
Covariance (intercept, time)	0.198	0.074	NP
Residual variance	4.871	0.083	NP

Once mental health at baseline was included in the models, the effect estimates shifted towards the null, yet remained statistically significant for VF consumption until adjustment for lifestyle behaviours (physical activity, screen time, sleep, tobacco smoking and vaping, binge drinking, cannabis use) and for SSB consumption following the full adjustment. In females, the change of one serving per year in VF consumption was associated with 0.23-point lower CESD-R-10 scores, and the one-point change per year of the SSB composite score was associated with 0.12-point higher CESD-R-10 score (Table 4.3). These associations were evident in males, albeit the magnitude was substantially weaker compared to these associations in females. Although both initial levels and rates of change of VF and SSB consumption were associated with anxiety symptoms in unadjusted models, these associations were nullified following adjustment for anxiety symptoms at baseline.

Discussion

In this prospective cohort study of 5,653 Canadian adolescents, we found that diets deteriorate during middle adolescence, with a decrease in VF and increase in SSB consumption. These changes were found to be associated with the severity of depressive symptoms. We found no associations of changes over time in VF and SSB consumption with anxiety symptoms, regardless of sex.

In this study, more than 80% of participants reported consuming SSB during a usual week. Consumption of SSB is estimated to contribute between 10% to 15% of the total caloric daily intake in adolescents. Being the primary source of added sugar in adolescents' diet,[29] SSB have previously been linked to plethora of negative physical health outcomes, including overweight and obesity, type 2 diabetes, cardiovascular diseases, and dental caries. Detrimental impact of SSB consumption on mental health has also been previously elucidated.[27] To date, public health efforts to promote healthy diet have traditionally centered around improving VF consumption. Results of this study provide additional evidence that underscores the importance of broadening the scope of preventive actions. Given the abundance and increased availability of SSB, it is time to develop and implement policy interventions (sugar taxation, product labelling, subsidies for healthful foods) that target SSB and excess sugar consumption.[30,31] A recently published World Health Organization manual on sugar-sweetened beverage taxation policies emphasizes that the introduction of SSB taxes can be a "win-win-win strategy" in that 1) the public benefits from the increased health equity, 2) public health – from averting healthcare costs, and 3) governments – from generating additional revenue.[32] Public health experience over the past decade suggests that promoting healthier diets at the population level is challenging. Results of this study provide

novel evidence that may be used to nudge dietary changes at the population level. Increasing the public's awareness of broader benefits of healthy eating may improve the previously low success rates of population level interventions.[33]

Moreover, given that unhealthy diet is one of the shared risk factors for both physical and mental health, advocating for a shared framework for the prevention of common mental and noncommunicable diseases should also be considered.[34] Our results show that the associations of interest appear stronger in female adolescents, which could mean that targeting female adolescents could be potentially promising: according to the Developmental Origins of Health and Disease theory,[35] healthy dietary habits, when established in young females, will eventually be passed on to future generations. Yet, the effect sizes for females and males are not substantially different, and we argue that primary prevention and promotion interventions for mental health implemented at the population level and thus targeting all young people should be considered.

None of the examined associations were apparent for anxiety symptoms. Anxiety is commonly combined with depression into an umbrella term called "internalizing disorders", since they are the most common and often co-occurring mental disorders in adolescence. However, anxiety's etiology is likely distinct from that of depression (which is currently considered an inflammatory disease[36]), with lifestyle behaviours playing a less prominent role in it. Indeed, the strongest predictor of anxiety disorders is female sex, with psychological and parental psychopathology factors appearing to play a role as well, albeit to a lesser degree.[37]

This study has several strengths. First of all, we used an alternative approach to conceptualizing diet in adolescence. While repeated measures of dietary consumption are commonly operationalized as the mean of repeated measurements, the difference between measurements, or using generalized estimating equations and mixed models,[38] we used individual growth modeling to derive estimates of initial level and rate of change of the VF and SSB trajectories. Second, unhealthy diet also co-occurs with other unhealthy lifestyle behaviours (including substance use behaviours), and it is important to adjust for a comprehensive range of lifestyle behaviours that commonly occur in adolescence when assessing diet-mental health relationship. The indiscriminate adjustment for covariates in extant studies has been previously highlighted,[4,26] including the omission of key confounders (e.g., socioeconomic status, baseline mental health) and inclusion of potential mediators (e.g., body mass index). To circumvent these challenges, we developed an evidence-based causal model and identified a set of confounders of the diet-mental health relationship (details available in Chapter 3).

Several limitations warrant consideration. The use of screener questions to assess dietary consumption, commonly recognized as a reductionist approach, used in COMPASS precludes comprehensive assessment of diet. Having access to detailed dietary data undoubtedly offers opportunities to conceptualize dietary exposures in ways that better reflect the complexity of diet. Yet, there are no cohort studies of Canadian middle adolescents that collect information on both comprehensive dietary assessment (e.g., based on multiple 24-h dietary recalls) and mental health. Next, the self-report measures of all individual-level variables do not exclude the possibility of social desirability and recall biases: for example, it is possible that VF consumption is overestimated, and SSB consumption is underestimated. Nonetheless, the reported associations

would be likely biased towards the null,[39] and thus it is important to keep in mind that the magnitude of true associations is likely stronger. Finally, since dietary data were collected at three time points, we considered only the linear functional form of dietary trajectories; repeat observations across four and more time points would allow researcher to consider non-linear functional forms of dietary trajectories in future research.

Conclusion

In this prospective cohort panel of Canadian middle adolescents, we showed that consumption of VF and SSB deteriorates over time, and that the rate at which these changes happen is associated with the severity of depressive symptoms (but not anxiety symptoms). These results call for dietary interventions at the population level to counteract these downward changes in diet during adolescence to help reduce the growing mental health burden in youth.

Table 4.3. Initial levels and rates of change in VF and SSB consumption between 2016/17 and 2018/19 in relation to mental health outcomes in 2018/19, with sequential adjustment for covariates included in the minimally sufficient adjustment set.

	Unadjusted	Model 1	Model 2	Model 3	Model 4	Model 5		
						Total	Female	Male
	β (95% CI)*	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)
Depressive symptoms								
FV consumption, servings/day								
Initial level	**-0.27 (-0.35, -0.18)**	**-0.09 (-0.16, -0.03)**	**-0.09 (-0.16, -0.03)**	**-0.07 (-0.14, -0.01)**	-0.04 (-0.10, 0.03)	-0.02 (-0.08, 0.05)	-0.04 (-0.13, 0.06)	0.00 (-0.09, 0.09)
Rate of change	**-0.47 (-0.64, -0.29)**	**-0.19 (-0.32, -0.05)**	**-0.18 (-0.31, -0.04)**	**-0.16 (-0.30, -0.03)**	-0.13 (-0.27, 0.00)	-0.12 (-0.25, 0.02)	**-0.23 (-0.42, -0.04)**	0.02 (-0.17, 0.20)
SSB consumption								
Initial level	**0.20 (0.15, 0.25)**	**0.04 (0.00, 0.08)**	**0.05 (0.01, 0.09)**	**0.04 (0.00, 0.08)**	0.02 (-0.02, 0.06)	0.02 (-0.02, 0.06)	0.03 (-0.03, 0.09)	0.00 (-0.05, 0.05)
Rate of change	**0.32 (0.22, 0.42)**	**0.13 (0.05, 0.21)**	**0.14 (0.07, 0.22)**	**0.13 (-.05, 0.21)**	**0.11 (0.03, 0.19)**	**0.10 (0.03, 0.18)**	**0.12 (0.01, 0.23)**	0.07 (-0.03, 0.18)
Anxiety symptoms								
FV consumption, servings/day								
Initial level	**-0.14 (-0.22, -0.07)**	-0.02 (-0.08, 0.04)	-0.02 (-0.08, 0.05)	0.00 (-0.06, 0.06)	0.03 (-0.03, 0.09)	0.04 (-0.02, 0.10)	-0.00 (-0.09, 0.09)	0.07 (-0.02, 0.16)
Rate of change	**-0.26 (-0.42, -0.09)**	-0.09 (-0.22, 0.04)	-0.07 (-0.20, 0.06)	-0.05 (-0.18, 0.07)	-0.02 (-0.14, 0.11)	-0.01 (-0.13, 0.12)	-0.06 (-0.23, 0.12)	0.05 (-0.13, 0.23)
SSB consumption								
Initial level	**0.14 (0.10, 0.19)**	0.03 (-0.01, 0.06)	0.04 (0.01, 0.08)	0.03 (-0.00, 0.07)	0.01 (-0.02, 0.05)	0.01 (-0.03, 0.05)	-0.01 (-0.06, 0.05)	0.03 (-0.02, 0.08)
Rate of change	**0.22 (0.13, 0.31)**	0.06 (-0.01, 0.14)	0.08 (0.01, 0.16)	0.07 (-0.00, 0.14)	0.05 (-0.02, 0.12)	0.05 (-0.03, 0.12)	0.04 (-0.07, 0.14)	0.06 (-0.04, 0.16)

*β (95% CI) obtained from linear mixed-effects models and refer to the change in depressive and anxiety scale scores for every unit increase in explanatory variables. Model 1 adjusted for mental health at baseline, Model 2 – additionally adjusted for quintile of neighbourhood material deprivation, age and sex, Model 3 – additionally adjusted for breakfast skipping and weight loss attempts, Model 4 – additionally adjusted for physical activity, screen time, sleep, tobacco smoking and vaping, binge drinking, cannabis use, and Model 5 – additionally adjusted for supportive social relationships and happy family life. All covariates were measured in 2017/18.

References

1. Wiens K, Bhattarai A, Pedram P, Dores A, Williams J, Bulloch A, et al. A growing need for youth mental health services in Canada: examining trends in youth mental health from 2011 to 2018. *Epidemiol Psychiatr Sci.* 2020;29:e115.
2. SickKids. *COVID-19: guidance for school operation during the pandemic.* SickKids. 2021. https://www.sickkids.ca/en/news/archive/2021/covid19_updated_guidance_school operation-during-pandemic/
3. Racine N, McArthur BA, Cooke JE, Eirich R, Zhu J, Madigan S. Global prevalence of depressive and anxiety symptoms in children and adolescents during Covid-19: a meta-analysis. *JAMA Pediatr*. 2021;175(11):1142–50.
4. Khalid S, Williams CM, Reynolds SA. Is there an association between diet and depression in children and adolescents? A systematic review. *Br J Nutr*. 2016;116(12):2097–108.
5. Orlando L, Savel KA, Madigan S, Colasanto M, Korczak DJ. Dietary patterns and internalizing symptoms in children and adolescents: a meta-analysis. *Aust N Z J Psychiatry*. 2022;56(6):617-641.
6. Dawson SL, Dash SR, Jacka FN. The importance of diet and gut health to the treatment and prevention of mental disorders. In: *International review of neurobiology*. Elsevier; 2016. p. 325–46.
7. Lassale C, Batty GD, Baghdadli A, Jacka F, Sánchez-Villegas A, Kivimäki M, et al. Healthy dietary indices and risk of depressive outcomes: a systematic review and meta-analysis of observational studies. *Mol Psychiatry*. 2018;24(7):965–86.
8. Reedy J, Subar AF, George SM, Krebs-Smith SM. Extending methods in dietary patterns research. *Nutrients*. 2018;10(5).
9. Statistics Canada. *Correlates of vaping among adolescents in Canada*. 2022. https://www150.statcan.gc.ca/n1/pub/82-003-x/2022007/article/00003-eng.htm
10. Canadian Public Health Association. *Tobacco and vaping use in Canada: moving forward*. 2021. https://www.cpha.ca/tobacco-and-vaping-use-canada-moving-forward
11. Health Canada. *Summary of results for the Canadian Student Tobacco, Alcohol and Drugs Survey 2018-19*. 2022. https://www.canada.ca/en/health-canada/services/canadian-student-tobacco-alcohol-drugs-survey/2018-2019-summary.html
12. Esteban-Gonzalo L, Turner AI, Torres SJ, Esteban-Cornejo I, Castro-Pinero J, Delgado-Alfonso A, et al. Diet quality and well-being in children and adolescents: the UP&DOWN longitudinal study. *Br J Nutr*. 2019;121(2):221–31.
13. McMartin SE, Kuhle S, Colman I, Kirk SF, Veugelers PJ. Diet quality and mental health in subsequent years among Canadian youth. *Public Health Nutr*. 2012;15(12):2253–8.
14. Wilson J, Blizzard L, Gall S, et al. Youth diet quality and hazard of mood disorder in adolescence and adulthood among an Australian cohort. *J Affect Disord*. 2020;276:511-8.
15. Winpenny EM, van Harmelen AL, White M, van Sluijs EMF, Goodyer IM. Diet quality and depressive symptoms in adolescence: no cross-sectional or prospective associations following adjustment for covariates. *Public Health Nutr*. 2018;21(13):2376–84.
16. Wu X, Bastian K, Ohinmaa A, Veugelers P. Influence of physical activity, sedentary behavior, and diet quality in childhood on the incidence of internalizing and externalizing disorders during adolescence: a population-based cohort study. *Ann Epidemiol*. 2018;28(2):86–94.

17. Jacka FN, Rothon C, Taylor S, Berk M, Stansfeld SA. Diet quality and mental health problems in adolescents from East London: a prospective study. *Soc Psychiatry Psychiatr Epidemiol*. 2013;48(8):1297–306.
18. Jacka FN, Kremer PJ, Berk M, et al. A prospective study of diet quality and mental health in adolescents. *PloS One*. 2011;6(9):e24805.
19. 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):1-7.
20. Methods for linking COMPASS student-level data over time. COMPASS System. 2015. https://uwaterloo.ca/compass-system/publications/methods-linking-compass-student-level-data-over-time
21. Bradley KL, Bagnell AL, Brannen CL. Factorial validity of the Center for Epidemiological Studies Depression 10 in adolescents. *Issues Ment Health Nurs*. 2010;31(6):408–12.
22. Spitzer RL, Kroenke K, Williams JBW, Löwe B. A brief measure for assessing generalized anxiety disorder: the GAD-7. *Arch Intern Med*. 2006;166(10):1092–7
23. Tiirikainen K, Haravuori H, Ranta K, Kaltiala-Heino R, Marttunen M. Psychometric properties of the 7-item Generalized Anxiety Disorder Scale (GAD-7) in a large representative sample of Finnish adolescents. *Psychiatry Res*. 2019;272:30–5.
24. Godin KM, Chaurasia A, Hammond D, Leatherdale ST. Food purchasing behaviors and sugar-sweetened beverage consumption among Canadian secondary school students in the COMPASS Study. *J Nutr Educ Behav*. 2018;50(8):803-12.
25. Pampalon R, Raymond G. A deprivation index for health and welfare planning in Quebec. *Chronic Dis Can*. 2000;21(3):104–13.
26. Molendijk M, Molero P, Ortuno Sanchez-Pedreno F, Van der Does W, Angel Martinez-Gonzalez M. Diet quality and depression risk: a systematic review and dose-response meta-analysis of prospective studies. *J Affect Disord*. 2018;226:346–54.
27. Hu D, Cheng L, Jiang W. Sugar-sweetened beverages consumption and the risk of depression: A meta-analysis of observational studies. *J Affect Disord*. 2019;245:348-55.
28. StataCorp. Stata Statistical Software: Release 17. College Station, TX: StataCorp LLC; 2021.
29. Hu FB, Malik VS. Sugar-sweetened beverages and risk of obesity and type 2 diabetes: epidemiologic evidence. *Physiol Behav*. 2010;100(1):47–54.
30. Veugelers PJ, Taylor JP, Ohinmaa A, Liu S, Munasinghe LL, Maximova K. To tax or not to tax? That's the sugar-coated question. *Can J Public Health*. 2022;113(5):786-7.
31. Canadian Paediatric Society. *A proposal to increase taxes on sugar-sweetened beverages in Canada*. Canadian Paediatric Society. 2020. https://cps.ca/en/documents/position/tax-on-sugar-sweetened-beverages
32. World Health Organization. *WHO manual on sugar-sweetened beverage taxation policies to promote healthy diets*. Geneva, Switzerland: World Health Organization; 2022 https://www.who.int/publications-detail-redirect/9789240056299
33. Brambila-Macias J, Shankar B, Capacci S, Mazzocchi M, Perez-Cueto FJ, Verbeke W, et al. Policy interventions to promote healthy eating: a review of what works, what does not, and what is promising. *Food Nutr Bull*. 2011;32(4):365–75.

34. O'Neil A, Jacka FN, Quirk SE, Cocker F, Taylor CB, Oldenburg B, et al. A shared framework for the common mental disorders and non-communicable disease: key considerations for disease prevention and control. *BMC Psychiatry*. 2015;15:15.
35. Barker M. Developmental origins, behaviour change and the new public health. *J Dev Orig Health Dis*. 2015;6(5):428–33.
36. Berk M, Williams LJ, Jacka FN, O'Neil A, Pasco JA, Moylan S, et al. So depression is an inflammatory disease, but where does the inflammation come from? *BMC Medicine*. 2013;11:200.
37. Narmandakh A, Roest AM, de Jonge P, Oldehinkel AJ. Psychosocial and biological risk factors of anxiety disorders in adolescents: a TRAILS report. *Eur Child Adolesc Psychiatry*. 2021;30(12):1969–82.
38. Lukomskyj N, Allman-Farinelli M, Shi Y, Rangan A. Dietary exposures in childhood and adulthood and cardiometabolic outcomes: a systematic scoping review. *J Hum Nutr Diet*. 2021;34(3):511–23.
39. Subar AF, Freedman LS, Tooze JA, Kirkpatrick SI, Boushey C, Neuhouser ML, et al. Addressing current criticism regarding the value of self-report dietary data. *J Nutr*. 2015;145(12):2639–45.

Chapter 5: The impact of 12 modifiable lifestyle behaviours on depressive and anxiety symptoms in middle adolescence: prospective analyses of the Canadian longitudinal COMPASS study.

Dabravolskaj J, Veugelers PJ, Amores A, Leatherdale ST, Patte KA, Maximova K. The impact of 12 modifiable lifestyle behaviours on depressive and anxiety symptoms in middle adolescence: prospective analyses of the Canadian longitudinal COMPASS study. [IJBNPA, in press]

Abstract

Background: Unhealthy lifestyle behaviours are becoming increasingly common and might contribute to the growing burden of mental disorders in adolescence. We examined the associations between a comprehensive set of lifestyle behaviours and depression and anxiety in middle adolescents.

Methods: School-based survey responses were collected from 24,274 Canadian high school students at baseline and 1-year follow-up (average age 14.8 and 15.8 years, respectively). Using linear mixed-effects models, we examined prospective associations of adherence to recommendations for vegetables and fruit, grains, milk and alternatives, meat and alternatives, sugar-sweetened beverages [SSB], physical activity, screen time, sleep, and no use of tobacco, e-cigarettes, cannabis, and binge drinking at baseline with the depressive and anxiety symptoms (measured by CESD-R-10 and GAD-7 scales, respectively) at follow-up.

Results: Adherence to recommendations was low overall, particularly for vegetables and fruit (3.9%), grains (4.5%), and screen time 4.9%). Students adhering to individual recommendations, particularly for meat and alternatives, SSB, screen time, sleep, and no cannabis use, at baseline

had lower CESD-R-10 and GAD-7 scores at follow-up. Adhering to every additional recommendation was associated with lower CESD-R-10 (β=-0.15, 95% CI -0.18, -0.11) and GAD-7 scores (β=-0.10, 95% CI -0.14, -0.07) at follow-up. Assuming cumulative impact, this might translate into 7.2- and 4.8-point lower CESD-R-10 and GAD-7 scores, respectively, among students adhering to 12 vs. 0 recommendations over four years of high school.

Conclusions: The results highlight the preventive potential of population-based approaches promoting healthy lifestyle behaviours, particularly those with the lowest prevalence, as a strategy to improve mental health in adolescence.

Chapter 5

Introduction

Mental health problems are becoming increasingly common among adolescents in Canada, as reflected in the increasing rates of related healthcare visits even before the COVID-19 pandemic. For example, compared to stable rates of healthcare visits due to physical health conditions, there were 53% more emergency department and 74% more inpatient visits due to mental health problems (most commonly anxiety, mood, and substance use disorders) in 15-17-year-olds between 2006/07 and 2013/14.[1] Pandemic-related disruptions have further exacerbated the mental health burden in adolescents, with noted increases in the proportion of mental health-related hospitalizations and the use of mood and anxiety medications.[2] This underscores the urgent need for population-based health promotion and primary prevention[3] that, in the absence of effective treatment options, are a crucial strategy to curb the mental health burden.

The evidence on the detrimental impact that substance use (i.e., tobacco smoking, binge drinking,[4] vaping,[5] cannabis use[6]), lack of physical activity, excess screen time,[7] or poor sleep[8] each individually have on the development of mental health problems is strong, and the importance of healthy diet is emerging too.[9,10] Studies generally focus on the impact of individual lifestyle behaviours, but this does not augment our understanding of the intricate relationships among lifestyle behaviours which tend to cluster among adolescents,[11–13] and how these intertwined behaviours may be linked to mental health. Several studies quantified associations between belonging to different clusters of lifestyle behaviours and mental health outcomes in adolescents.[14,15] While interesting, such studies often examine different combinations of a limited number of lifestyle behaviours and/or assess them using different scales, thus making results across studies difficult to compare. Operationalizing lifestyle

behaviours in terms of adherence to existing evidence-based recommendations (which remain mostly unchanged over the years and comparable across countries) can help circumvent these challenges. Additionally, results of studies examining adherence to lifestyle recommendations in relation to mental health outcomes can be easier to understand by public health professionals and thus conducive to being implemented in practice.

To our knowledge, there is only one prospective study[16] that has estimated the effect of overall adherence to nine lifestyle recommendations (i.e., vegetables and fruit, grains, milk and alternatives, meat and alternatives, added sugar, saturated fat, sleep, screen time, physical activity) on the risk of developing internalizing and externalizing mental disorders in *early adolescence* (i.e., ages 10-14). However, as adolescents mature, they gain more independence, their social relationships become more complex and influential,[17] and as a result they often adopt new unhealthy behaviours, particularly substance use behaviours, often initiated around the age of 15.[18,19] In fact, 30% of middle adolescents (i.e., 14-17 years) reported binge drinking, e-cigarette smoking (vaping), and drug use in 2018/19.[20] Given this high prevalence of substance use behaviours, it is imperative to evaluate a wide range of lifestyle behaviours in relation to mental health outcomes in middle adolescence. To date, no Canadian study has examined the extent to which the co-occurrence of a full range of lifestyle behaviours (including substance use) may relate to mental illness in this age group. Therefore, the goal of this study is two-fold: 1) to examine individual and overall adherence to 12 lifestyle recommendations (i.e., five recommendations for diet and one each for physical activity, screen time, sleep, and no tobacco smoking, vaping, cannabis use, and binge drinking), and 2) to assess the relationship between adherence to these recommendations and the severity of depressive and anxiety symptoms

among Canadian middle adolescents. We hypothesized that both individually and in combination, healthier lifestyle behaviours are prospectively associated with better mental health in middle adolescence.

Methods

The Cannabis, Obesity, Mental health, Physical activity, Alcohol, Smoking, and Sedentary behaviour (COMPASS) is a large longitudinal study that annually collects survey data on an extensive range of lifestyle behaviours from more than 65,000 grade 9-12 students (age 13-18 years) recruited through a convenience sample of 122 secondary schools in Alberta, British Columbia, Ontario, and Québec, Canada.[21] Using an active-information passive-consent parental permission protocol, students complete an anonymous COMPASS questionnaire at school during class time. COMPASS procedures are available elsewhere.[21] For this study, we linked[22] participants' responses from 2017/18 (average age of participants 14.8 [SD=1.2] years old) to the same participants' responses from 2018/19 (average age 15.8 [SD=1.2] years old). Records of grade 12 participants and those who changed schools between 2017/18 and 2018/19 were not linked: out of 66,434 participants from 122 schools in 2017/18, the linked sample comprised records of 29,022 participants from 116 schools. Analyses were based on a subsample of 24,274 participants, with data available for all variables listed below. Response rates in 2017/18 and 2018/19 were 81.8% and 84.2%, respectively, with non-response being mainly due to absenteeism or scheduled spare time during data collection.[23]

Measures

The Center for Epidemiologic Studies Depression Scale Revised-10 (CESD-R-10)[24] is a 10-item self-report scale that queries participants about the frequency of symptoms of unipolar depression in the last seven days (none or <1 day; 1-2 days; 3-4 days; and 5-7 days). The Generalized Anxiety Disorder-7 (GAD-7) scale[25] is a 7-item self-report scale that asks participants about the frequency of generalized anxiety disorder symptoms in the last two weeks (not at all; several days; over half the days; and nearly every day). Both scales demonstrated strong psychometric properties in adolescents.[26,27] On both scales, items are scored from 0 to 3. Scores are then summed, with the final scores ranging from 0 to 30 for CESD-R-10 and 0 to 21 for GAD-7 scales. Higher scores on both scales indicate greater severity of symptoms. For both scales, missing values on up to two items were imputed for 5168 participants.[28–30]

Adherence to established recommendations[31–35] was conceptualized as both individual and overall adherence to recommendations for: vegetables and fruit, grains, milk and alternatives, meat and alternatives, sugar-sweetened beverages (SSB), physical activity, screen time, sleep, and no use of tobacco, e-cigarettes, cannabis, and binge drinking. Participants reported the number of servings (up to nine or more) of *vegetables and fruit, grain products, milk and alternatives,* and *meat and alternatives* they consumed the previous day.[36] Participants reported the number of days in a usual school week when they consumed sugar-sweetened beverages, high-energy drinks, and coffee or tea with sugar, which were combined into a *sugar-sweetened beverages* composite variable (SSB). Participants reported the number of minutes of *moderate-to-vigorous physical activity* (MVPA) on each day in the past week; the number of hours and minutes per day they usually spend watching/streaming TV shows or movies, playing

video/computer games, talking on the phone, surfing the Internet, and texting, messaging, emailing, which were summed to obtain total daily *screen time*[37]; and the number of hours and minutes per day they usually *sleep.* Participants reported the past-30-days frequency of smoking one or more *cigarettes* and *e-cigarettes* (vaped) (none, 1, 2-3, 4-5, 6-10, 11-20, 21-29, 30 days) and the past-12-months frequency of *cannabis use* (never, used but not in the past 12 months, less than once/month, once/month, 2-3 times/month, once/week, 2-3 times/week, 4-6 times/week, and every day) and of having five or more drinks of alcohol on one occasion (i.e., *binge drinking*) (never, not in the past 12 months, less than once/month, once/month, 2-3 times/month, once/week, 2-5 times/week, daily or almost daily). Participants that never tried cigarettes, cannabis use, and binge drinking were considered as those meeting recommendations. Participants' responses to questions pertaining to each lifestyle behaviour were assigned 0 points if a recommendation was not met and 1 point if it was met (Table 5.1).

Table 5.1. Existing recommendations for 12 lifestyle behaviours in adolescents in Canada

Lifestyle behaviour	**Recommendation met if:†**
Vegetables and fruit, servings/day	females ≥ 7, males ≥8
Grain products, servings/day	females ≥ 6, males ≥7
Milk and alternatives, servings/day	females and males ≥ 3
Meat and alternatives, servings/day	females ≥ 2, males ≥ 3
SSB, servings/day	0
MVPA, minutes/day	≥60
Screen time, hours/day	<2
Sleep, hours/day	8-10
Tobacco smoking	no tobacco smoking ever or in the past 30 days
Vaping	no vaping in the past 30 days
Cannabis use	no cannabis use ever or in the past 12 months
Binge drinking	no binge drinking ever or in the past 12 months

SSB: sugar-sweetened beverages; MVPA: moderate-to-vigorous physical activity.
†The Canada's Food Guide (2011) was used to determine adherence to recommendations for vegetables and fruit, grain products, milk and alternatives, meat and alternatives[31]; the Canada's Food Guide (2021) – for SSB;[38] the

Canadian 24-hour movement guidelines – for MVPA, screen time and sleep.[32] Substance use behaviours are not recommended.[33–35]

Points for all lifestyle behaviours were then summed to create a composite score ranging from 0 to 12, with higher scores indicating higher overall adherence to lifestyle recommendations and thus a healthier lifestyle. Additionally, based on the composite score, participants were categorized into those having very unfavourable (meeting ≤3 recommendations), unfavourable (4-6), intermediate (7-9), or favourable (10-12) lifestyles.

Covariates

A-priori-defined confounders were *age* (years), *sex* (female, male), *ethnicity* (White, Black, Hispanic, Asian, Other/Mixed), *school area urban class* (rural area and small [population of 1,000-29,999], medium [30,000-99,999], and large urban [≥100,000] population centers, defined by the 2016 Canadian Census[39]), *school-area median household income* ($20,000-$40,000, $40,001-$60,000, $60,001-$80,000, and more than $80,000, derived from the first three letters of each school's postal code), *weight status* (derived from self-reported height and weight and categorized into underweight, normal weight, overweight, obese, and missing according to age- and sex-specific cut-off points[40]), *weight perception* (very or slightly underweight, about the right weight, slightly or very overweight), and *weight loss attempts* (positive responses to the statement "[I am] trying to lose weight"). The latter three covariates were included to account for the potentially confounding effect of these variables on associations between lifestyle behaviours, particularly diet and physical activity, and mental health outcomes.

Data analyses

We used Student's *t*-test and analysis of variance (ANOVA) tests to assess differences in mean CESD-R-10 and GAD-7 scores. We estimated 1-year prospective associations between individual and overall adherence to lifestyle recommendations at baseline and the severity of depressive and anxiety symptoms at 1-year follow-up. Univariate and multivariable linear mixed-effects models (LMMs) were used to account for the nested data structure (i.e., students in schools). Multivariable models were first adjusted for age, ethnicity, school area urban class, school-area median household income, weight status, weight perception, weight loss attempts, and mental health at baseline (CESD-R-10 and GAD-7 scores, as appropriate) (Model 1). Next, these models were repeated while being mutually adjusted for other lifestyle behaviours (Model 2) to quantify the *individual effect* of separate lifestyle behaviours on the severity of depressive and anxiety symptoms in those meeting vs. not meeting recommendations. In this study, we consider lifestyle behaviours as competing exposures and their relationships with mental health outcomes to be similarly confounded. To compare the *combined effect* of all 12 lifestyle behaviours on the severity of depressive and anxiety symptoms in those with unfavourable, intermediate, and favourable lifestyles (i.e., meeting 4-6, 7-9, and 10-12 recommendations, respectively) vs. very unfavourable lifestyle (i.e., meeting ≤3 recommendations), we ran models adjusting for the same covariates as Model 1 described above. Finally, we ran the same models with the number of recommendations met as the independent variable to quantify the effect of adhering to each additional recommendation on the severity of depressive and anxiety symptoms. The final models were sex-stratified since lifestyle behaviours[41,42] and mental health[43] are sex-patterned. Missing baseline values for age, sex, and ethnicity were imputed based on the available information (e.g., age reported in 2018/19 minus one, and sex and ethnicity – same as

in 2018/19). All models were adjusted for confounders (and confounding is a causal concept[44]), therefore we use causal language throughout the manuscript for transparency and clarity.[45] Cross-sectional associations at baseline are reported in Appendices L and M but are not discussed in this paper. Analyses were performed using SAS 9.4 (SAS Institute, Cary, NC).

Results

Participant characteristics are provided in Table 5.2: 54.4% were female, 71.6% identified as white, 55.9% resided in large population centres, and 42.2% attended schools located in areas of higher median household income. More than half of the participants were classified as normal weight. Compared to males, females more often perceived themselves as normal weight (58.4% vs. 52.4%) and reported weight loss attempts (41.1% vs. 21.8%).

Only 3.9% of participants met recommendations for vegetables and fruit, 4.5% for grains, and 4.9% for screen time. Close to one-third (28.9%) met recommendations for SSB, 36.4% for milk and alternatives, and 38.5% for MVPA (Table 5.2). Recommendations for sleep and meat and alternatives were met by 48.3% and 55.4%, respectively. Three-quarters of participants reported no binge drinking, 83.5% no vaping, 86.4% no cannabis use, and 93.2% no tobacco smoking. On average, participants in this study met 5.6 recommendations, while almost none of the participants met all 12 recommendations. Overall, 70.0% of participants were classified as having very unfavourable or unfavourable lifestyles, while 29.3% had intermediate and 0.7% favourable lifestyles. No notable sex differences were observed in individual or overall adherence to 12 lifestyle recommendations.

At baseline and follow-up, CESD-R-10 scores were 8.03 (SD=5.70) and 8.92 (SD=5.99) and GAD-7 scores 5.85 (SD=5.30) and 6.47 (SD=5.50), respectively (Table 5.2). At baseline, CESD-R-10 and GAD-7 scores were lower among participants who followed recommendations for individual lifestyle behaviours, except for vegetables and fruit, and grains (Table 5.3). Those who were meeting recommendations for vegetables and fruit, and grains had similar CESD-R-10 scores and higher GAD-7 scores than those not meeting these recommendations. Participants with a very unfavourable lifestyle (i.e., meeting ≤3 recommendations) had generally higher CESD-R-10 and GAD-7 scores (10.60 [SD=6.42] and 7.89 [SD=5.89], respectively) compared to those with favourable lifestyle (5.49 [SD=4.76] and 3.87 [SD=4.90], respectively). This pattern was particularly pronounced in females.

When considered individually, adherence to lifestyle recommendations, particularly for meat and alternatives, SSB, screen time, sleep, and no cannabis use at baseline was associated with lower CESD-R-10 and GAD-7 scores at follow-up (Table 5.4). Sex-based subgroup analyses revealed some differences. Females adhering to recommendations for meat and alternatives, SSB, screen time, and sleep had lower severity of depressive and anxiety symptoms, while the opposite was observed for MVPA: contrary to expectations, adherence to the individual recommendation for MVPA was associated with higher severity of depressive symptoms. Males adhering to recommendations for SSB, MVPA, screen time, sleep, and cannabis use had lower severity of depressive and particularly anxiety symptoms.

As for the combined effect, for every additional lifestyle recommendation met, females (β=-0.13, 95% CI -0.18, -0.08) and males (β=-0.17, 95% CI -0.22, -0.12) had lower CESD-R-10 scores at

follow-up. Compared to those with the very unfavourable lifestyle (i.e., meeting ≤3 recommendations), females and males with the favourable lifestyle (i.e., meeting 10-12 recommendations) had lower CESD-R-10 scores (Table 5.5: β=-1.15, 95% CI -2.28, -0.02 and β=-1.35, 95% CI -2.28, -0.41, respectively) and males with unfavourable and intermediate (i.e., meeting 7-9 recommendations) lifestyles had lower GAD-7 scores (β=-0.29, 95% CI -0.54, -0.03 and β=-0.65, -0.93, -0.38, respectively) at follow-up. Given that students spend four years in high school and assuming the homogeneity and additivity of the effect of lifestyle behaviours on mental health outcomes throughout high school, these estimates may add up to 4.6- and 5.4-point lower CESD-R-10 scores in females and males with the favourable lifestyle and up to 1.16- and 2.6-point lower GAD-7 scores in males with the unfavourable and intermediate lifestyles, compared to those with the very unfavourable lifestyle. Cross-sectional estimates (Appendices L and M) were more pronounced than those in prospective analyses.

Discussion

In this study, we found adherence to 12 lifestyle behaviours in middle adolescence to be very low, particularly for vegetables and fruit, grains, and screen time with less than 5% of participants adhering to each of these recommendations. Participants reported adhering, on average, to 5.6 lifestyle recommendations and almost none adhering to all 12 recommendations. Adherence to recommendations for lifestyle behaviours, particularly for meat and alternatives, SSB, screen time, sleep, and no cannabis use, was prospectively associated with less severe depressive and anxiety symptoms in middle adolescents. When considered in combination, adolescents meeting 10-12 and 7-9 recommendations had lower CESD-R-10 scores and those meeting 7-9 recommendations had lower GAD-7 scores at follow-up, compared to those with the

very unfavourable lifestyle (i.e., meeting ≤3 recommendations). Moreover, adherence to each additional recommendation was associated with lower CESD-R-10 and GAD-7 scores at follow-up.

As mentioned before, there is only one prospective study that considered individual and combined effects of adherence to a range of lifestyle behaviours in relation to mental health outcomes, but it is limited to early adolescence. This study by Loewen et al. linked population-based survey data from 3,436 early adolescents (10-11 year old) to administrative records up to the age of 15. Early adolescents meeting 4-6 and 7-9 lifestyle recommendations had, respectively, 39% and 56% fewer healthcare visits for mental health problems in the following four years compared to those meeting 1-3 lifestyle recommendations.[16] Available studies on the combined effect (i.e., the impact of overall adherence to recommendations on mental health) in *older* adolescents are cross-sectional in design. For example, a study of 10,183 adolescents in grades 7-12 showed that meeting recommendations for sleep, screen time, and physical activity was linked to lower odds of suicidal ideation (odds ratio [OR]=0.24, 95% CI 0.09, 0.69) and suicide attempts (OR=0.08, 95% CI 0.02, 0.41) in male students.[46] Another cross-sectional study of 244,250 Norwegian adolescents aged 13-19 showed that those with higher overall adherence to recommendations for physical activity, screen time, tobacco smoking, and alcohol consumption had up to 60% lower odds of depressive symptoms.[47] Although results reported in these studies are encouraging, prospective effect estimates are more reliable since they consider baseline levels of mental health.

Prospective estimates reported in the current study should be considered through a population health lens. As Geoffrey Rose noted,[48] 'a large number of people at a small risk may give rise to more cases of disease than the small number who are at a high risk'. Although evidence shows that targeted prevention of mental disorders appear more effective and cost-effective than population-level prevention,[49] the latter covers not only those at increased risk of mental disorders, but serves as a protective shield for all children and adolescents.[50] Moreover, population-level prevention strategies for physical health conditions mostly target the same lifestyle behaviours (e.g., diet, physical activity, sedentary behaviour, screen time, substance use) as those aiming to prevent mental disorders, and therefore these strategies can be united under the shared framework for prevention of common mental and noncommunicable diseases.[51] If implemented throughout childhood and early adolescence, these interventions may be effective at curbing the increasing burden of both physical and mental health problems in the longer term.

The finding that females adhering to the physical activity recommendation tended to have higher depressive and anxiety symptoms is surprising. The same finding, albeit only in relation to anxiety symptoms at 1-year follow-up, was previously reported in another COMPASS study.[52] One may speculate the influence of social desirability bias: female adolescents, aware of existing recommendations to engage in physical activity, might over-report their MVPA, particularly those who are overweight.[53] If the severity of mental health symptoms is also over-reported by female adolescents, it could contribute to this spurious association. Nonetheless, it remains unclear what could explain this counterintuitive relationship, given that physical activity is one of the most effective lifestyle interventions to promote mental health in adolescents.[54] Still, it

emphasizes the importance of conducting sex-based subgroup analyses to understand sex differences better.

Limitations

Several limitations are worth considering when interpreting study findings. First, data come from a convenience sample predominantly from schools located in large population centres and areas with higher school-area median income. Thus, the study findings may not be representative of adolescents in Canada. Second, all measures were self-reported, yet social desirability and recall bias might have been at least partially negated by the anonymous nature of the COMPASS questionnaire. Third, although many measures are based on previously validated national surveillance tools and guidelines, measurement error is possible, leading to misclassification.[21] Considering the trajectories of adherence to recommendations in relation to mental health outcomes could partly overcome the measurement error associated with the self-reported adherence to lifestyle recommendations, but given this study's short timeframe (i.e., one year), we assumed that trajectories of most lifestyle behaviours stayed fairly stable. Finally, analyses could be overpowered given the large sample size, and hence we focus on effect estimates rather than p-values in our interpretation of the results, as per current recommendations.[55,56]

Conclusion

In prospective analyses, we found that overall adherence to recommendations for a comprehensive set of lifestyle behaviours common in middle adolescents was associated with lower severity of depressive symptoms in females and males and anxiety symptoms in males one year later. These results support the public health message that making even modest positive

changes to lifestyle behaviours that increase overall adherence to lifestyle recommendations can improve mental health in adolescents. Given the multifactorial etiology of mental health problems, population-based approaches promoting healthy lifestyle behaviours, particularly those with the lowest prevalence (e.g., healthy eating, limited screen time), may yield the biggest improvement in mental health in adolescents, along with many other health, social, and developmental outcomes.

Table 5.2. Characteristics of participants (n=24,274) in the COMPASS study at baseline (2017/18 school year).

	Total (n=24,274)	**Females (n=13,204)**	**Males (n=11,070)**
Age, mean (SD)	14.8 (1.2)	14.8 (1.2)	14.8 (1.2)
Sex, %			
Females	54.4	N/A	N/A
Males	45.6	N/A	N/A
Ethnicity, %			
White	71.6	71.2	72.1
Black	2.6	2.4	2.8
Asian	10.6	10.7	10.5
Latin American/Hispanic	1.9	1.9	1.9
Other/mixed	13.3	13.8	12.7
Province, %			
Ontario	47.1	46.3	48.1
Alberta	5.1	4.9	5.2
British Columbia	13.9	13.6	14.4
Quebec	33.9	35.2	32.3
School area urban class, %			
Rural area	0.6	0.6	0.5
Small urban population centres	31.6	31.0	32.2
Medium urban population centres	11.9	11.9	12.1
Large urban population centres	55.9	56.5	55.2
School-area median income (CAD), %			
20,000 to 40,000	5.8	6.0	5.5
40,001 to 60,000	31.4	32.2	30.4
60,001 to 80,000	42.2	41.6	42.7
80,000+	20.6	20.2	21.4
Weight status, %			
Underweight	1.9	1.7	2.1
Normal weight	55.7	58.4	52.4
Overweight	12.1	10.5	14.0
Obese	5.4	3.8	7.2
Missing	24.9	25.6	24.3
Weight perception, %			
Underweight	16.3	11.5	21.9
About the right weight	60.8	63.5	57.7
Overweight	22.9	25.0	20.4
Weight loss attempts, %			
Yes	32.3	41.1	21.8
No	67.7	58.9	78.2
Adherence to individual recommendations for, %			

Vegetables and fruit	3.9	4.6	3.1
Grain products	4.5	3.8	5.3
Milk and alternatives	36.4	28.9	45.5
Meat and alternatives	55.4	65.0	43.9
SSB	28.9	30.8	26.7
MVPA	38.5	31.5	46.8
Screen time	4.9	5.8	3.8
Sleep	48.3	46.4	50.7
No tobacco smoking	93.2	94.3	91.9
No vaping	83.5	86.0	80.6
No cannabis use	86.4	87.1	85.6
No binge drinking	75.0	74.9	75.1
Number of recommendations met, %			
0	0.4	0.2	0.2
1	1.4	0.8	0.7
2	3.3	1.8	1.5
3	6.1	3.3	2.7
4	12.8	6.8	6.0
5	22.0	11.9	10.1
6	24.0	13.3	10.7
7	17.7	9.8	7.9
8	8.6	4.6	4.0
9	3.0	1.6	1.4
10	0.6	0.3	0.3
11	0.1	0.0	0.1
12	0.0	0.0	0.0
Number of recommendations met, mean (SD)	5.6 (1.7)	5.6 (1.7)	5.6 (1.8)
*Lifestyle based on overall adherence, %***			
Very unfavourable	11.1	11.1	11.2
Unfavourable	58.9	59.0	58.7
Intermediate	29.3	29.3	29.2
Favourable	0.7	0.6	0.9
CESD-R-10 score, mean (SD)	8.0 (5.7)	9.1 (6.1)	6.7 (4.8)
GAD-7 score, mean (SD)	5.9 (5.3)	7.2 (5.6)	4.3 (4.5)

CAD: Canadian dollar; MVPA: moderate-to-vigorous physical activity; SD: standard deviation; SSB: sugar-sweetened beverages.

**Those meeting 3 or less recommendations were classified as having very unfavourable, 4-6 – unfavourable, 7-9 – intermediate, and 10-12 – favourable lifestyles.

Table 5.3. CESD-R-10 and GAD-7 scores by adherence to lifestyle recommendations at baseline (mean age 14.8 years).

	Depressive symptoms (CESD-R-10 score)			**Anxiety symptoms (GAD-7 score)**		
	Total	**Females**	**Males**	**Total**	**Females**	**Males**
	Mean (SD)	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**
Adherence to individual recommendations for:						
Vegetables and fruit						
yes	7.94 (6.09)	8.71 (6.28)	6.56 (5.48)	6.16 (5.79)	7.18 (5.92)	4.31 (5.06)
no	8.04 (5.68)	9.15 (6.11)	6.72 (4.81)	5.83 (5.28)	7.17 (5.54)	4.27 (4.47)
Grain products						
yes	8.00 (5.71)	9.14 (6.11)	7.03 (5.15)	5.99 (5.49)	7.41 (5.77)	**4.77 (4.93)**
no	8.03 (5.70)	9.13 (6.12)	6.70 (4.81)	5.84 (5.29)	7.16 (5.55)	**4.24 (4.46)**
Milk and alternatives						
yes	**7.39 (5.46)**	**8.59 (6.10)**	**6.47 (4.73)**	**5.28 (5.12)**	**6.82 (5.59)**	**4.11 (4.40)**
no	**8.40 (5.80)**	**9.35 (6.12)**	**6.92 (4.90)**	**6.17 (5.37)**	**7.31 (5.54)**	**4.40 (4.56)**
Meat and alternatives						
yes	**7.81 (5.54)**	**8.55 (5.82)**	**6.50 (4.74)**	5.79 (5.15)	**6.71 (5.32)**	**4.16 (4.39)**
no	**8.31 (5.87)**	**10.21 (6.50)**	**6.89 (4.89)**	5.92 (5.47)	**8.02 (5.88)**	**4.36 (4.56)**
SSB						
yes	**7.30 (5.61)**	**8.13 (6.01)**	**6.15 (4.77)**	**5.19 (5.09)**	**6.26 (5.36)**	**3.72 (4.28)**
no	**8.33 (5.71)**	**9.57 (6.12)**	**6.93 (4.84)**	**6.11 (5.36)**	**7.57 (5.60)**	**4.47 (4.54)**
MVPA						
yes	**7.91 (5.69)**	**9.51 (6.24)**	**6.61 (4.83)**	5.77 (5.44)	**7.69 (5.78)**	4.23 (4.60)
no	**8.11 (5.70)**	**8.95 (6.06)**	**6.82 (4.83)**	5.89 (5.21)	**6.93 (5.44)**	4.31 (4.39)
Screen time						
yes	**6.15 (4.95)**	**6.70 (5.20)**	**5.15 (4.31)**	**4.68 (5.00)**	**5.49 (5.28)**	**3.20 (4.08)**
no	**8.13 (5.72)**	**9.28 (6.14)**	**6.78 (4.84)**	**5.91 (5.31)**	**7.27 (5.56)**	**4.31 (4.50)**
Sleep						
yes	**6.73 (5.04)**	**7.66 (5.55)**	**5.71 (4.18)**	**4.82 (4.76)**	**5.95 (5.08)**	**3.59 (4.05)**
no	**9.25 (6.00)**	**10.41 (6.30)**	**7.76 (5.22)**	**6.80 (5.59)**	**8.22 (5.74)**	**4.97 (4.80)**
No tobacco smoking						

yes	**7.83 (5.58)**	**8.88 (5.99)**	**6.55 (4.72)**	**5.70 (5.21)**	**6.97 (5.49)**	**4.14 (4.38)**
no	**10.78 (6.57)**	**13.32 (6.76)**	**8.63 (5.55)**	**7.84 (6.02)**	**10.33 (5.81)**	**5.75 (5.36)**
No vaping						
yes	**7.78 (5.59)**	**8.76 (5.99)**	**6.52 (4.74)**	**5.66 (5.21)**	**6.88 (5.47)**	**4.11 (4.40)**
no	**9.33 (6.05)**	**11.38 (6.42)**	**7.55 (5.09)**	**6.78 (5.63)**	**8.94 (5.79)**	**4.93 (4.77)**
No cannabis use						
yes	**7.66 (5.50)**	**8.65 (5.90)**	**6.46 (4.69)**	**5.56 (5.15)**	**6.79 (5.41)**	**4.06 (4.35)**
no	**10.38 (6.36)**	**12.36 (6.59)**	**8.25 (5.34)**	**7.65 (5.87)**	**9.67 (5.88)**	**5.50 (5.04)**
No binge drinking						
yes	**7.63 (5.50)**	**8.56 (5.92)**	**6.51 (4.70)**	**5.50 (5.16)**	**6.70 (5.45)**	**4.08 (4.38)**
no	**9.24 (6.11)**	**10.83 (6.38)**	**7.33 (5.14)**	**6.87 (5.58)**	**8.57 (5.64)**	**4.85 (4.76)**
Lifestyle based on overall adherence*						
Very unfavourable	**10.60 (6.42)**	**12.47 (6.61)**	**8.38 (5.43)**	**7.89 (5.89)**	**9.84 (5.80)**	**5.62 (5.13)**
Unfavourable	**8.34 (5.66)**	**9.47 (6.04)**	**6.98 (4.84)**	**6.05 (5.29)**	**7.40 (5.51)**	**4.42 (4.50)**
Intermediate	**6.52 (5.01)**	**7.27 (5.42)**	**5.61 (4.30)**	**4.71 (4.77)**	**5.73 (5.10)**	**3.48 (4.02)**
Favourable	**5.49 (4.76)**	**6.03 (5.15)**	**5.06 (4.39)**	**3.87 (4.90)**	**4.63 (5.21)**	**3.26 (4.57)**

MVPA: moderate-to-vigorous physical activity; SD: standard deviation; SSB: sugar-sweetened beverages

*Bolded are values with p-values <0.05.

**Those meeting 3 or less recommendations were classified as having very unfavourable, 4-6 – unfavourable, 7-9 – intermediate, and 10-12 –favourable lifestyles.

Table 5.4. Associations of adherence to 12 lifestyle recommendations at baseline with CESD-R-10 and GAD-7 scores at 1-year follow-up.

	Univariate	**Multivariable***			
		Model 1	**Model 2**		
	Total	**Total**	**Total**	**Females**	**Males**
	β (95% CI)	**β (95% CI)**	**β (95% CI)**	**β (95% CI)**	**β (95% CI)**
Adherence to individual recommendations for:			**Depressive symptoms**		
Vegetables and fruit	-0.29 (-0.68, 0.10)	**-0.40 (-0.71, -0.09)**	-0.26 (-0.57, 0.06)	-0.17 (-0.59, 0.24)	-0.45 (-0.95, 0.06)
Grain products	-0.35 (-0.71, 0.02)	-0.19 (-0.49, 0.10)	-0.06 (-0.36, 0.24)	-0.02 (-0.47, 0.44)	-0.11 (-0.51, 0.28)
Milk and alternatives	**-0.89 (-1.05, -0.73)**	-0.09 (-0.22, 0.04)	-0.03 (-0.16, 0.10)	-0.03 (-0.23, 0.16)	-0.04 (-0.22, 0.13)
Meat and alternatives	**-0.30 (-0.45, -0.14)**	**-0.28 (-0.41, -0.16)**	**-0.24 (-0.37, -0.11)**	**-0.38 (-0.56, -0.19)**	-0.10 (-0.28, 0.08)
SSB	**-0.76 (-0.93, -0.59)**	**-0.28 (-0.42, -0.15)**	**-0.20 (-0.34, -0.06)**	-0.19 (-0.38, 0.00)	**-0.22 (-0.42, -0.03)**
MVPA	**-0.46 (-0.62, -0.31)**	0.05 (-0.08, 0.18)	0.08 (-0.05, 0.21)	**0.31 (0.12, 0.50)**	**-0.19 (-0.36, -0.01)**
Screen time	**-1.79 (-2.14, -1.44)**	**-0.76 (-1.04, -0.48)**	**-0.65 (-0.93, -0.36)**	**-0.76 (-1.13, -0.39)**	-0.41 (-0.86, 0.04)
Sleep	**-1.98 (-2.13, -1.83)**	**-0.49 (-0.62, -0.37)**	**-0.45 (-0.58, -0.33)**	**-0.53 (-0.71, -0.34)**	**-0.38 (-0.56, -0.20)**
No tobacco smoking	**-1.89 (-2.20, -1.59)**	-0.24 (-0.48, 0.01)	-0.03 (-0.31, 0.26)	0.02 (-0.40, 0.45)	-0.03 (-0.41, 0.35)
No vaping	**-1.02 (-1.23, -0.81)**	**-0.19 (-0.36, -0.02)**	-0.04 (-0.24, 0.16)	0.10 (-0.18, 0.39)	-0.16 (-0.43, 0.11)
No cannabis use	**-1.81 (-2.03, -1.59)**	**-0.36 (-0.55, -0.18)**	**-0.29 (-0.51, -0.07)**	-0.23 (-0.55, 0.09)	**-0.37 (-0.68, -0.06)**
No binge drinking	**-1.09 (-1.26, -0.91)**	-0.12 (-0.27, 0.03)	0.06 (-0.12, 0.23)	0.06 (-0.18, 0.31)	0.06 (-0.19, 0.30)
Adherence to individual recommendations for:			**Anxiety symptoms**		
Vegetables and fruit	0.32 (-0.03, 0.68)	-0.07 (-0.35, 0.21)	0.01 (-0.27, 0.29)	0.00 (-0.36, 0.37)	-0.02 (-0.48, 0.44)
Grain products	-0.07 (-0.41, 0.26)	0.02 (-0.24, 0.29)	0.07 (-0.20, 0.34)	-0.04 (-0.45, 0.36)	0.15 (-0.20, 0.50)
Milk and alternatives	**-0.71 (-0.85, -0.57)**	0.04 (-0.07, 0.16)	0.08 (-0.04, 0.19)	0.09 (-0.09, 0.26)	0.06 (-0.10, 0.22)
Meat and alternatives	0.09 (-0.05, 0.23)	**-0.19 (-0.30, -0.08)**	**-0.19 (-0.30, -0.07)**	**-0.27 (-0.44, -0.11)**	-0.08 (-0.25, 0.08)
SSB	**-0.66 (-0.81, -0.51)**	**-0.26 (-0.38, -0.14)**	**-0.19 (-0.31, -0.07)**	**-0.21 (-0.38, -0.04)**	**-0.19 (-0.37, -0.01)**
MVPA	**-0.42 (-0.56, -0.27)**	0.09 (-0.03, 0.20)	0.10 (-0.02, 0.21)	**0.29 (0.13, 0.46)**	-0.11 (-0.27, 0.05)
Screen time	**-1.14 (-1.46, -0.82)**	**-0.64 (-0.89, -0.39)**	**-0.55 (-0.80, -0.29)**	**-0.60 (-0.93, -0.27)**	**-0.46 (-0.86, -0.06)**
Sleep	**-1.53 (-1.67, -1.39)**	**-0.40 (-0.51, -0.29)**	**-0.37 (-0.49, -0.26)**	**-0.32 (-0.49, -0.16)**	**-0.46 (-0.62, -0.30)**
No tobacco smoking	**-1.36 (-1.63, -1.09)**	-0.15 (-0.37, 0.07)	0.10 (-0.15, 0.35)	0.19 (-0.18, 0.56)	0.02 (-0.31, 0.36)

No vaping	**-0.82 (-1.01, -0.64)**	**-0.23 (-0.38, -0.08)**	-0.13 (-0.31, 0.04)	-0.12 (-0.38, 0.13)	-0.08 (-0.32, 0.16)
No cannabis use	**-1.47 (-1.67, -1.26)**	**-0.34 (-0.50, -0.17)**	**-0.29 (-0.49, -0.10)**	-0.15 (-0.44, 0.13)	**-0.49 (-0.77, -0.22)**
No binge drinking	**-0.98 (-1.14, -0.82)**	-0.09 (-0.23, 0.04)	0.11 (-0.05, 0.26)	0.15 (-0.06, 0.37)	0.07 (-0.15, 0.28)

β: unstandardized regression coefficient; 95% CI: 95% confidence interval; MVPA: moderate-to-vigorous physical activity; SSB: sugar-sweetened beverages.
*In linear mixed-effects models, Model 1 was adjusted for age, ethnicity, weight status, weight perception, weight loss attempts, school- area median household income, school area urban class, and mental health at baseline (CESD-R-10 and GAD-7 scores, as appropriate). Model 2 was adjusted for the covariates listed for Model 1 and mutually adjusted for all other lifestyle behaviours. Not meeting recommendations was the reference category in all analyses presented in Table 5.4.
95% CIs that do not include the null value are bolded.

Table 5.5. Associations of overall adherence to 12 lifestyle recommendations at baseline with CESD-R-10 and GAD-7 scores at 1-year follow-up.

	Univariate	Multivariable*		
	Total	Total	Females	Males
	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)
*Lifestyle based on overall adherence***		***Depressive symptoms***		
Unfavourable	**-1.45 (-1.69, -1.20)**	-0.15 (-0.35, 0.06)	0.04 (-0.25, 0.33)	**-0.35 (-0.64, -0.07)**
Intermediate	**-2.87 (-3.14, -2.61)**	**-0.54 (-0.77, -0.32)**	**-0.33 (-0.65, -0.01)**	**-0.80 (-1.11, -0.49)**
Favourable	**-4.17 (-5.07, -3.28)**	**-1.22 (-1.95, -0.49)**	**-1.15 (-2.28, -0.02)**	**-1.35 (-2.28, -0.41)**
Per recommendation met:	**-0.59 (-0.63, -0.55)**	**-0.15 (-0.18, -0.11)**	**-0.13 (-0.18, -0.08)**	**-0.17 (-0.22, -0.12)**
Lifestyle based on overall adherence		***Anxiety symptoms***		
Unfavourable	**-1.24 (-1.46, -1.01)**	-0.13 (-0.31, 0.05)	0.03 (-0.23, 0.28)	**-0.29 (-0.54, -0.03)**
Intermediate	**-2.24 (-2.48, -2.00)**	**-0.40 (-0.60, -0.20)**	-0.17 (-0.45, 0.11)	**-0.65 (-0.93, -0.38)**
Favourable	**-2.90 (-3.72, -2.08)**	-0.40 (-1.06, 0.25)	-0.54 (-1.54, 0.46)	-0.33 (-1.17, 0.51)
Per recommendation met:	**-0.44 (-0.48, -0.40)**	**-0.10 (-0.14, -0.07)**	**-0.07 (-0.12, -0.03)**	**-0.13 (-0.18, -0.09)**

β: unstandardized regression coefficient; 95% CI: 95% confidence interval; SSB: sugar-sweetened beverages; MVPA: moderate-to-vigorous physical activity.
*Multivariable linear mixed-effects models were adjusted for age, ethnicity, weight status, weight perception, weight loss attempts, school-area median household income, school area urban class, and mental health at baseline (CESD-R-10 and GAD-7 scores, as appropriate). Meeting 3 or less recommendations was the reference category in analyses where lifestyle based on overall adherence was the independent variable. CIs that do not include the null value are bolded.
**Those meeting 3 or less recommendations were classified as having very unfavourable, 4-6 – unfavourable, 7-9 – intermediate, and 10-12 – favourable lifestyles.

References

1. Canadian Institute for Health Information. *Care for children and youth with mental disorders*. 2015. https://secure.cihi.ca/estore/productFamily.htm?locale=en&pf=PFC2866.
2. Canadian Institute for Health Information. *Children and youth mental health in Canada*. 2022. https://www.cihi.ca/en/children-and-youth-mental-health-in-canada.
3. Canadian Public Health Association. *A public health approach to population mental wellness*. 2021. https://www.cpha.ca/public-health-approach-population-mental-wellness.
4. Cairns KE, Yap MBH, Pilkington PD, Jorm AF. Risk and protective factors for depression that adolescents can modify: a systematic review and meta-analysis of longitudinal studies. *J Affect Disord*. 2014;169:61–75.
5. Becker TD, Arnold MK, Ro V, Martin L, Rice TR. Systematic review of electronic cigarette use (vaping) and mental health comorbidity among adolescents and young adults. *N&TR*. 2021;23(3):415–25.
6. Gobbi G, Atkin T, Zytynski T, Wang S, Askari S, Boruff J, et al. Association of cannabis use in adolescence and risk of depression, anxiety, and suicidality in young adulthood. A systematic review and meta-analysis. *JAMA Psychiatry*. 2019;76(4):426–34.
7. Asare M. Sedentary behaviour and mental health in children and adolescents: a meta-analysis. *J Child Adolesc Behav*. 2015;03(06).
8. Lovato N, Gradisar M. A meta-analysis and model of the relationship between sleep and depression in adolescents: recommendations for future research and clinical practice. *Sleep Med Rev*. 2014;18(6):521–9.
9. Khalid S, Williams CM, Reynolds SA. Is there an association between diet and depression in children and adolescents? A systematic review. *Br J Nutr*. 2016;116(12):2097–108.
10. Orlando L, Savel KA, Madigan S, Colasanto M, Korczak DJ. Dietary patterns and internalizing symptoms in children and adolescents: a meta-analysis. *Aust N Z J Psychiatry*. 2021;00048674211031486.
11. Alamian A, Paradis G. Clustering of chronic disease behavioral risk factors in Canadian children and adolescents. *Prev Med*. 2009;48(5):493–9.
12. deRuiter WK, Cairney J, Leatherdale S, Faulkner G. The period prevalence of risk behavior co-occurrence among Canadians. *Prev Med*. 2016;85:11–6.
13. 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;17:102.
14. Gardner LA, Champion KE, Grummitt L, Chapman C, Sunderland M, Thornton L, et al. Clustering of six key risk behaviors for chronic disease among adolescent females. *Int J Environ Res Public Health*. 2020;17(19):1–12.
15. Champion KE, Mather M, Spring B, Kay-Lambkin F, Teesson M, Newton NC. Clustering of multiple risk behaviors among a sample of 18-year-old Australians and associations with mental health outcomes: a latent class analysis. *Front Public Health*. 2018;6(101616579):135.
16. Loewen OK, Maximova K, Ekwaru JP, Faught EL, Asbridge M, Ohinmaa A, et al. Lifestyle behavior and mental health in early adolescence. *Pediatrics*. 2019;143(5):e20183307.
17. Umberson D, Crosnoe R, Reczek C. Social relationships and health behavior across life course. *Annu Rev Sociol*. 2010;36:139–57.

18. Statistics Canada. *Correlates of vaping among adolescents in Canada*. 2022. https://www150.statcan.gc.ca/n1/pub/82-003-x/2022007/article/00003-eng.htm.
19. Canadian Public Health Association. *Tobacco and vaping use in Canada: moving forward*. 2021. https://www.cpha.ca/tobacco-and-vaping-use-canada-moving-forward.
20. Health Canada. *Summary of results for the Canadian Student Tobacco, Alcohol and Drugs Survey 2018-19*. 2022. Available from: https://www.canada.ca/en/health-canada/services/canadian-student-tobacco-alcohol-drugs-survey/2018-2019-summary.html.
21. Leatherdale ST, Brown KS, Carson V, Childs RA, Dubin JA, Elliott SJ, 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 Apr 8;14:331.
22. Battista K, Qian W, Bredin C, Leatherdale ST. Student data linkage over multiple years. Technical Report Series. Waterloo, Ontario: University of Waterloo. 2019;6(3). https://uwaterloo.ca/compass-system/student-data-linkage-over-multiple-years.
23. Burns KE, Vermeer J, Battista K, Leatherdale ST. A School-level examination of the association between programs and policies and physical activity outcomes among females from the COMPASS Study. *Int J Environ Res Public Health*. 2021;18(6):3314.
24. Andresen EM, Malmgren JA, Carter WB, Patrick DL. Screening for depression in well older adults: evaluation of a short form of the CES-D (Center for Epidemiologic Studies Depression Scale). *Am J Prev Med*. 1994 Apr;10(2):77–84.
25. Spitzer RL, Kroenke K, Williams JBW, Löwe B. A brief measure for assessing generalized anxiety disorder: the GAD-7. *Arch Intern Med*. 2006;166(10):1092–7.
26. Haroz EE, Ybarra M, Eaton WW. Psychometric evaluation of a self-report scale to measure adolescent depression: the CESDR-10 in two national adolescent samples in the United States. *J Affect Disord*. 2014;158:154–60.
27. Tiirikainen K, Haravuori H, Ranta K, Kaltiala-Heino R, Marttunen M. Psychometric properties of the 7-item Generalized Anxiety Disorder Scale (GAD-7) in a large representative sample of Finnish adolescents. *Psychiatry Res*. 2019;272:30–5.
28. Downey RG, King C. Missing data in Likert ratings: A comparison of replacement methods. *J Gen Psychol*. 1998 Apr;125(2):175–91.
29. Bono C, Ried LD, Kimberlin C, Vogel B. Missing data on the Center for Epidemiologic Studies Depression Scale: a comparison of 4 imputation techniques. *Res Social Adm Pharm*. 2007 Mar;3(1):1–27.
30. Romano I, Ferro MA, Patte KA, Leatherdale ST. Measurement invariance of the GAD-7 and CESD-R-10 among adolescents in Canada. *J Pediatr Psychol*. 2022;47(5):585–94.
31. Health Canada. *Eating Well with Canada's Food Guide*. 2011. https://www.canada.ca/content/dam/hc-sc/migration/hc-sc/fn-an/alt_formats/hpfb-dgpsa/pdf/food-guide-aliment/print_eatwell_bienmang-eng.pdf. Accessed 22 Sep 2019.
32. Tremblay MS, Carson V, Chaput JP, Connor Gorber S, Dinh T, Duggan M, 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.
33. Health Canada. *Smoking, vaping and tobacco*. 2015. https://www.canada.ca/en/health-canada/services/smoking-tobacco.html.
34. Drug Free Kids Canada. *Youth and alcohol*. https://www.drugfreekidscanada.org/wp-content/uploads/2019/10/DFK_Info_YouthAlcohol_FINAL.pdf.

35. Drug Free Kids Canada. *Vaping*. https://www.drugfreekidscanada.org/prevention/issues/vaping/.
36. 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;10:42.
37. Leatherdale S, Laxer RE, Faulkner G. *Reliability and validity of the physical activity and sedentary behaviour measures in the COMPASS study*. COMPASS Technical Report Series. Waterloo, Ontario: University of Waterloo. 2014;2(1). https://uwaterloo.ca/compass-system/publications/reliability-and-validity-physical-activity-and-sedentary.
38. Health Canada. *Canada's Food Guide*. 2021. https://www.canada.ca/en/health-canada/services/canada-food-guides.html.
39. Statistics Canada. *Census Profile, 2016 Census*. 2017. https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/index.cfm?Lang=E.
40. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ*. 2000;320(7244):1240-3.
41. Hyde JS, Mezulis AH, Abramson LY. The ABCs of depression: integrating affective, biological, and cognitive models to explain the emergence of the gender difference in depression. *Psychol Rev*. 2008;115(2):291-313.
42. Angold A, Costello EJ. Puberty and depression. *Child Adolesc Psychiatr Clin N Am*. 2006;15(4):919–37.
43. Breslau J, Gilman SE, Stein BD, Ruder T, Gmelin T, Miller E. Sex differences in recent first-onset depression in an epidemiological sample of adolescents. *Transl Psychiatry*. 2017;7(5):e1139.
44. Hernán MA. The C-word: scientific euphemisms do not improve causal inference from observational data. *Am J Public Health*. 2018;108(5):616–9.
45. Haber NA, Wieten SE, Rohrer JM, Arah OA, Tennant PWG, Stuart EA, et al. Causal and associational language in observational health research: a systematic evaluation. *Am J Epidemiol*. 2022;191(12):2084–97.
46. Sampasa-Kanyinga H, Chaput JP, Goldfield GS, Janssen I, Wang J, Hamilton HA, et al. 24-hour movement guidelines and suicidality among adolescents. *J Affect Disord*. 2020;274:372–80.
47. Kleppang AL, Haugland SH, Bakken A, Stea TH. Lifestyle habits and depressive symptoms in Norwegian adolescents: a national cross-sectional study. *BMC Public Health*. 2021;21(1):816.
48. Rose G. Sick individuals and sick populations. *Int J Epidemiol*. 2001;30(3):427–32.
49. Le LKD, Esturas AC, Mihalopoulos C, Chiotelis O, Bucholc J, Chatterton ML, et al. Cost-effectiveness evidence of mental health prevention and promotion interventions: a systematic review of economic evaluations. *PLoS Med*. 2021;18(5):e1003606.
50. Fenwick-Smith A, Dahlberg EE, Thompson SC. Systematic review of resilience-enhancing, universal, primary school-based mental health promotion programs. *BMC Psychol*. 2018;6(1):30.
51. O'Neil A, Jacka FN, Quirk SE, Cocker F, Taylor CB, Oldenburg B, et al. A shared framework for the common mental disorders and non-communicable disease: key considerations for disease prevention and control. *BMC Psychiatry*. 2015;15:15.

52. Buchan MC, Romano I, Butler A, Laxer RE, Patte KA, Leatherdale ST. Bi-directional relationships between physical activity and mental health among a large sample of Canadian youth: a sex-stratified analysis of students in the COMPASS study. *Int J Behav Nutr Phys Act*. 2021;18(1):132.
53. McMurray RG, Ward DS, Elder JP, Lytle LA, Strikmiller PK, Baggett CD, et al. Do overweight girls overreport physical activity? *Am J Health Behav*. 2008;32(5):538–46.
54. Hu MX, Turner D, Generaal E, Bos D, Ikram MK, Ikram MA, et al. Exercise interventions for the prevention of depression: a systematic review of meta-analyses. *BMC Public Health*. 2020;20(1):1255.
55. Cummins KM, Marks C. Farewell to bright-line: a guide to reporting quantitative results without the S-word. *Front Psychol*. 2020;doi:10.3389/fpsyg.2020.00815
56. Wasserstein RL, Schirm AL, Lazar NA. Moving to a world beyond "p < 0.05." *Am Stat*. 2019;73(sup1):1–19.

Chapter 6: Discussion

Before discussing the results of the studies included in this dissertation, with their practical implications, limitations and strengths, and directions for future research, I would like to highlight the central place of theory in this work. Since randomized prevention studies to estimate the effect of diet (as well as that of other lifestyle behaviours) on mental disorders in adolescents are not available, we have no choice but to rely on modelling techniques guided by subject-matter knowledge.[1] In the late 1980s, Petitti noted that epidemiologic literature is often limited to the mechanical application of multivariate analyses.[2] While the field of epidemiology has progressed in the past decades, there is still truth to her statement. In essence, this dissertation was an attempt to step away from this practice by using graphical causal models to explicate the diet-mental health relationship in adolescents prior to engaging in data analyses.

As Galea and Hernan[3] noted, "in principle, almost anything can be a remote cause of anything in the future" and that "our goal as epidemiologists cannot be limited to establishing causation. Magnitude and importance of effects also matter" (p. 183). Thus, in this dissertation, the main question was not that of a binary nature ("Is there a causal relationship between diet and mental disorders in adolescence?"); the existing debates are briefly outlined in Chapter 1. Instead, I believe that one way or another, there *is* a causal relationship between diet and mental health in adolescence. The more important question (from a practical standpoint at least) is, "What is the magnitude of the effect of diet (alone and in combination with other lifestyle behaviours) on mental disorders in adolescents?" This is the central question that this dissertation attempts to answer.

Summary of findings

With that in mind, in ***Chapter 2***, I led a systematic review of 12 studies (eight cross-sectional, one case-control, and three prospective cohort studies) on the link between diet (conceptualized as vegetables and fruit consumption) and common mental disorders (i.e., depression and anxiety) in adolescence. While case-control and cross-sectional studies pointed to consistent associations between vegetables and fruit consumption and common mental disorders (i.e., depressive and anxiety disorders), these associations were considerably weaker in prospective cohort studies. Among the most pressing methodological concerns highlighted in this systematic review were inadequate adjustment for established confounders (e.g., socio-economic status), unnecessary adjustment for variables that might qualify as intermediate variables (e.g., weight status), and the need for sensitivity and sex-based subgroup analyses. These methodological concerns were addressed in subsequent chapters of this dissertation.

To address confounding bias, a causal model (directed acyclic graph [DAG]) was developed using the ESC-DAG approach;[4] this model encompasses the assumptions about the relationships between variables explicating the diet-mental health relationship. This DAG allowed us to identify the minimally sufficient adjustment set of confounders that included the following: mental health at baseline, socio-economic status, age, eating behaviours, lifestyle behaviours (i.e., physical activity, sedentary behaviours, sleep, and substance use behaviours, including tobacco smoking, vaping, cannabis and alcohol use), and social support. Once the minimally sufficient adjustment set was identified, several prospective cohort studies that collected both dietary and mental health data among Canadian middle adolescents (i.e., 14–17 years old) were considered for subsequent data analyses. Only one longitudinal study called the “Cannabis,

Obesity, Mental health, Physical activity, Alcohol, Smoking, and Sedentary behaviour" study, or COMPASS, collects data on both diet and mental health in middle adolescence, as well as other variables included in the minimally sufficient adjustment sets or their proxy variables. Therefore, COMPASS study was used in all data analyses.

In ***Chapter 3***, DAG-informed regression analyses in a sample of 13,887 Canadian adolescents who participated in the COMPASS study, showed a small positive effect of vegetables and fruit consumption on psychological wellbeing, but not on common mental disorders (i.e., depressive and anxiety symptoms). At the same time, a small negative effect was shown for SSB consumption on all mental health outcomes (i.e., depressive and anxiety symptoms, psychological wellbeing). Given the small effect sizes, E-values reported in sensitivity analyses were small too, meaning that even a "weak" confounder could completely nullify these associations of interest. Nevertheless, since I followed a systematic approach to constructing the causal model and examining potential confounders, the minimally sufficient adjustment set already captures the strongest confounders of the diet-mental health relationship, such as mental health at baseline, SES, social support, and others. Moreover, the sensitivity analyses showed that inclusion of other covariates (outside of the minimally sufficient adjustment set, but that were commonly adjusted for in other studies) did not change effect estimates. However, this does not negate the importance of developing other causal models. As our understanding of the intricate web of causation in nutritional epidemiology evolves, it is possible that other sources of residual confounding could emerge.

In ***Chapter 4***, a methodological gap that has received attention in the literature but has not yet been addressed in existing studies was the focus of inquiry: diet is often measured only at one time point, despite it being a dynamic exposure. One of the possible strategies for data analyses (apart from complex causal inference statistical approaches, such as the g-computational algorithm formula, inverse probability of treatment weighting of marginal structural models, or g-estimation of structural nested models[5]) is to consider individual dietary trajectories – specifically, initial levels (intercepts) and rates of change (slopes) in dietary exposures – as independent variables. In a prospective cohort panel of 5,653 Canadian adolescents in the COMPASS study, change in vegetables and fruit and SSB consumption over time was associated with depressive symptoms (slightly stronger in female adolescents), but no associations were evident with anxiety symptoms, regardless of sex.

Lastly, in ***Chapter 5***, I adopted a holistic approach to account for the synergistic effect that a range of co-occurring unhealthy lifestyle behaviours is hypothesized to have on health, including mental health. One explanation for the phenomenon of lifestyle behaviours co-occurring is the *problem-behaviour theory*, formulated by Jessor & Jessor,[6] that suggests a presence of an underlying behavioural syndrome that stems from the imbalance of risk and protective factors across multiple domains (e.g., personality, socio-environmental) and thus drives the adoption of multiple unhealthy lifestyle behaviours. The implication of this theory in this dissertation, and in Chapter 5 specifically, is that all lifestyle behaviours could be considered competing exposures as they are likely descendants of the same latent variable; health consciousness, the level of health education, health attitudes of closest peers could be examples of such latent variable.

Thus, in Chapter 5, diet (conceptualized as adherence to recommendations for vegetables and fruit, grains, meat and alternatives, milk and alternatives, and SSB consumption) was considered alone and in combination with seven other lifestyle behaviours (adherence to recommendations for physical activity, screen time, sleep, and no use of tobacco, e-cigarettes, cannabis, and binge drinking). When considered individually, adherence to recommendations for some of the lifestyle behaviours (i.e., for meat and alternatives, SSB, screen time, sleep, and no cannabis use) was associated with less severe depressive and anxiety symptoms at one-year follow-up in middle adolescents. When considered in combination, meeting more recommendations was generally associated with lower severity of depressive and anxiety symptoms at one-year follow-up, with adherence to each additional recommendation being associated with lower CESD-R-10 and GAD-7 scores at one-year follow-up.

Interpretation of relatively small magnitude of associations

In all studies included in this dissertation, reported effect sizes were of relatively small magnitude, which – as emphasized in Chapter 3 – are not evidence of no effect.[7] Indeed, as Rockhill mentioned in her seminal paper *Theorizing about causes at the individual level while estimating effects at the population level: implications for prevention*, most effect sizes for isolated risk factors *are* small.[8] There is no doubt that the etiology of mental disorders is multifactorial, with a complex web of multiple causal risk and protective factors interacting over the span of individuals' lives and at different levels (e.g., individual, population).[9] It was previously suggested by Jacka et al.[10] that genetic predisposition (unlike all other isolated factors) might account for a large proportion of the variance in mental disorders in adolescence. However, a recent study that utilized data from large population-based and case-control

samples[11] did not support this hypothesis. None of the previously hypothesized 18 candidate genes were associated with depression, with no support for any polymorphism-by-environment moderator effects. The authors concluded that previous studies in support of depression candidate genes were likely false positives. Another explanation of these effect sizes lies in the importance of time: as the accumulation of risk model[12] postulates, every additional year of exposure is associated with an increased risk of poor outcomes. This could explain why there is consistent evidence for a larger magnitude of associations, coming from observational[13] and randomized controlled trials,[14] in adults.

Comparing the effect estimates reported in this dissertation to those reported for other lifestyle behaviours might help contextualize these findings. Let us consider physical activity, sedentary behaviour, and substance use as these lifestyle behaviours are more strongly associated with mental disorders in adolescence. For example, in a meta-analysis of prospective cohort studies on the association of physical activity with incident depression in adolescents, adjusted odds ratio was 0.90 (95% CI 0.83, 0.98).[15] Other meta-analyses showed that higher sedentary behaviour and higher cannabis use were associated with 1.14 (95% CI: 1.08, 1.20)[16] and 1.37 (95% CI 1.16, 1.62)[17] higher odds of depressive symptoms in adolescents. The effect sizes for diet reported in this dissertation appear much smaller than those for physical activity, sedentary behaviour, and cannabis use. However, it is worth considering the efficacy of pharmacotherapeutic approaches in the management of major depressive disorder in adolescents: fluoxetine (the drug of choice in this age group) is the only drug that is slightly more effective than a placebo (SMD=−0.51, 95% Credible Interval -0.99, -0.03), and this low efficacy comes with very low tolerability in this age group.[18]

Practical implications

These seemingly small effect sizes are unlikely to convince individuals to change their behaviour,[8] particularly adolescents whose lifestyle is heavily influenced by peers (even more so than by siblings).[19,20] Thus, strategies at the individual level (e.g., individual risk communication) in adolescents might be negated by the influence of peers. Instead (and given that lifestyle behaviours are so tightly linked to the societal context), population-level interventions are much more appealing as they rely on the "abilities of societies and communities to create, or, in some cases, re-create, environments and activities of daily living so that more individuals readily and easily act in ways that will improve or maintain health for as long as possible" [8] (p. 127). Moreover, shifting social norms and context towards healthier ones help alleviate the disadvantages of the population-level approach, such as low motivation and the prevention paradox (i.e., "a preventive measure which brings much benefit to the population offers little to each participating individual "[21] [p.38]) and ensure sustainability of the intervention and its effect. The latter is certainly reflected in the economic burden of mental disorders. As a recent modeling study on the global return on investment from interventions that aim to prevent and treat mental disorders in adolescents showed, the universal prevention interventions for anxiety, depression and suicide in adolescents is cost-effective and has very high return on investment (ROI 147.4).[22]

Let us also consider the results of this dissertation through the lens of a recently formulated framework for *consequential epidemiology*, which aims to "understand what matters most, so we can do the most good" [3] (p. 183). Keyes and Galea argue that consequentialist epidemiology requires "explication of which factors, from the ubiquitous to the rare, are likely to have a large

population effect, and […] to assess the public health effect of these factors" [23] (p. 308). As we know, interventions targeting factors which are prevalent in the population and/or have considerable effects on health outcomes of interest yield the greatest benefit.[8] As per Keyes and Galea, this is what determines what is "consequential for public health" (p. 308), along with the prevalence of health conditions under study. Indeed, the high prevalence of unhealthy diet and depressive and anxiety symptoms (particularly among females), along with small but existing association between these two concepts, indicate that improving diet might be, if not a crucial lever for improving mental health in adolescents, then at least one worth considering.

Should diet be used as the only lifestyle factor targeted by mental health prevention interventions? The answer is simple: certainly not. Way too often, population-level interventions focus on isolated lifestyle behaviours simply because these interventions are often easier to implement, in contrast with comprehensive interventions that target multiple lifestyle behaviours. Yet, the results reported in Chapter 5 point to the combined effect of co-occurring unhealthy lifestyle behaviours on mental health in adolescents, thus supporting the need for prevention programs that take a holistic approach and tackle multiple modifiable lifestyle behaviours.

Moreover, these comprehensive population-level interventions will certainly produce positive effects on physical health as well, since diet is an established risk factor for many noncommunicable diseases (e.g., diabetes, obesity). Given that the analyses in this dissertation revealed an effect of diet (specifically, sugar-sweetened beverages) on mental disorders in adolescents, these results further support the need to advocate for the *shared framework for mental and physical health recommendations*[10] and the approach outlined in the World Health

Organization's report called "Prevention of mental disorders: effective interventions and policy options."[24] This report emphasizes that comprehensive population-level mental health prevention programs should: 1) address multiple mental and physical health conditions to yield social and economic benefits; and 2) be integrated into existing programs and social policies in multiple settings.

Dietary interventions as part of these comprehensive population-level programs should target the *determinants* of unhealthy diet (e.g., physical and economic environments)[25] in order to shift the distribution towards healthier diets by changing the food ecosystem. Interventions implemented at the policy level are critical to bringing about this change.[26] A recent publication in the Journal of the American Medical Association articulated seven policy-level public health interventions implementation of which is sorely needed to prevent diet-related chronic diseases: taxation of sugar-sweetened beverages, reduction of sodium levels in processed foods, implementation of nutrition labels that are visible and easy to understand to the public, banning food marketing to children, subsidizing healthy foods to low-income families, labelling unhealthful foods on restaurant menus, and launching counter-advertising campaigns that promote healthier diets.[27]

On the use of causal language

Before discussing the limitations of this dissertation and future research directions, it is important to comment on the causal language used sparingly throughout this dissertation. In the past decade, there has been a growing movement toward transparency in observational epidemiology. A paper published by Hernán[28] claims that simply ditching causal language "does not solve the tension between causation and association; it just sweeps it under the rug" (p. 617). A recently

published systematic evaluation of causal language used in high-profile medical/public health/epidemiology literature further elaborates on this point.[29] The authors emphasize that the confusion around associational vs. causal language is widespread and that avoiding "causal" words does not lead to clarity of interpretation. Indeed, the effort to shed light on the diet-mental health relationship and identify confounders was driven by our goal to answer a causal rather than an associational question. In addition, in line with existing guidelines,[30] p-values are not reported in this dissertation and are not discussed. Instead, guided by recommendations outlines by Rothman,[31] the focus was on confidence intervals to indicate both the magnitude and precision (random error) of the associations, and exploring the sources and magnitude of systematic errors (e.g., confounding) that could affect the associations of interest.

Strengths, limitations, and directions for future research

Major strengths of this dissertation include a systematic approach to building a causal model to describe one of the potential pathways linking diet and mental health in adolescence and access to a unique, large longitudinal study that collects a comprehensive set of variables relevant to the diet-mental health relationship. However, there are limitations worth considering. The first one being the dietary measures used in this study. While every attempt was made to identify prospective Canadian studies that collect detailed dietary data in middle adolescents, this proved to be a difficult task, with some studies collecting rich dietary data but no data on mental health, or vice versa. Conceptualizing diet in more comprehensive ways, for example as diet quality, ideally derived from multiple 24-hour dietary recalls is certainly desired, and pre-defined dietary indices (e.g., Diet Quality Index-International [DQI-I], Healthy Eating Index [HEI], Dietary Approaches to Stop Hypertension [DASH]) could yield a more accurate assessment of diet.[32]

Nevertheless, the consumption of vegetables and fruit has long been considered one of the crucial components of all healthy dietary patterns,[33] with the inadequate consumption of vegetables and fruit being associated with various health conditions.[34] Hence, many evidence-based nutritional guidelines center around the number of servings of vegetables and fruit.[35]Sugar-sweetened beverages consumption, given its prevalence in the general population,[36] emerged as another important dietary measure to consider.

Additionally, it has been previously recommended to develop and utilize methods that would allow us to account for the measurement error associated with self-reported dietary measures.[37–40] One such method is to adjust for total energy intake.[32,41] However, it requires the use of objective methods (e.g., doubly labelled water), which are usually too costly and impractical to assess in a large-scale cohort study or at least in a subset of participants as part of a calibration/validation substudy.[42] Data on total energy intake was not collected as part of the COMPASS study, and there is also new evidence suggesting that it might no longer be advisable.

Tomova et al.[43] contended the problematic nature of all four models commonly used to adjust for energy intake: adjustment for total energy intake, adjustment for remaining energy intake, rescaling dietary exposures as a proportion of total energy intake, and adjustment for total energy intake by using a residual. The authors advise instead to adjust for all dietary components (i.e., "all-components model"). Due to the scarcity of dietary data in COMPASS, this was not possible, and it is unlikely that adjusting for other dietary variables available in COMPASS (i.e., servings a day of meat and alternatives, milk and alternatives, and grain products) would be sufficient to get at the less biased estimates of dietary intake.

Like any variable in epidemiologic studies,[44] mental health and confounders adjusted for in analyses presented in this dissertation are imperfectly measured as well, and the measured and true values will always differ.[42] The goal is to understand the structure of measurement errors and estimate measurement bias;[45] in this case, the difference between the true and the measured associations of diet and mental health relationship. The structure of measurement bias (i.e., dependent vs. independent, differential vs. non-differential) depends on the methods of exposure and outcome assessment. The measurement bias is minimal when measurement errors for the exposure and outcome are independent and non-differential. However, measurement errors for diet and mental health in the COMPASS study are likely dependent and differential, since both diet and mental health are assessed using self-reported questionnaires. Nonetheless, mental health is measured using validated and established scales (i.e., CESD-R-10 and GAD-7), commonly used in population-based studies and validated in adolescents.[46,47]

As mentioned earlier, the evidence-based causal model is one of the strengths in this dissertation, yet it is important to highlight that the construction of any causal model requires collaborative, interdisciplinary work,[48] since the accuracy of causal estimates depends upon how closely the DAG matches the *true* data generating process, and the true data generating process can never be known.[49] Therefore, the DAG proposed in this dissertation is one of an infinite number of causal models that could potentially explain the focal diet–mental health relationship. Subsequent revision of the model based upon other expert knowledge (e.g., nutritionists, psychologists), plausible assumptions, and available theory are required. Additionally, novel approaches (e.g., DAGWOOD framework[50]) are emerging that provide iterative processes for generating and

critically appraising causal models and their underlying assumptions. Of course, while every attempt was made to tackle the issue of confounding by constructing the evidence-based casual model, the assumption of no unmeasured or residual confounding can never be verified in observational epidemiology.[51]

We might also consider comorbidity of depressive and anxiety disorders during data analyses: for example, when modelling depressive symptoms at 1-year follow-up, adjust not only for baseline depressive symptoms but also baseline anxiety symptoms. In the analyses presented in the current dissertation, we omitted this adjustment from the main analyses for two reasons: 1) adjustment for both baseline depressive and anxiety symptoms is uncommon, as evident in the studies included in the systematic review by Molendijk et al.[52]; and 2) we treated anxiety and depressive symptoms as two separate psychopathologies, with their distinct biological pathways. As part of post-hoc analyses, final models in Chapter 3 (see Appendix N) were re-ran and co-adjusted, but the changes in the effect estimates were minor and the interpretation of the findings would remain the same.

Molendijk et al.[52] also note that studies which examine different exposures and outcome measures at multiple points in time are required. This dissertation attempted to tackle this gap in the existing evidence by considering vegetables and fruit and sugar-sweetened beverages consumption in relation to depressive and anxiety symptoms (as well as psychological wellbeing in Chapter 3). Future research would benefit from triangulating evidence from multiple studies that collect rich dietary and mental health data: causal inference cannot be derived from single studies, no matter how well they are designed.[53] As Krieger and Davey Smith outline, “robust

causal inference… comprises a complex narrative, created by scientists appraising, from diverse perspectives, different strands of evidence produced by myriad methods" (p.1789). Therefore, the authors call for a "flexible, multi-faceted and historically-informed approach to causal inference" (p.1789) and for epidemiologists to pay more attention to "inference to the best explanation" approach (IBE). IBE is concerned with triangulation of evidence, driven by theory, extant knowledge and evidence, rather than solely by logic or probabilities.[53] Therefore, evidence from *multiple* prospective cohort studies, using different data sources (with different bias structures), assessment methods, and analytical approaches[54] are beneficial to guide causal inference in nutritional epidemiology. Work is currently underway to develop methods of determining the bounds of causal effects from effect estimates in multiple studies.[54]

Additionally, as novel approaches in causal inference are being developed, there is an opportunity to further fine-tune the causal question at hand. Under the target trial framework,[28] it might be possible to quantify the changes in mental disorders that we might expect if we were able to manipulate diet in adolescents. To do this, we could emulate a randomized controlled trial using observational data. However, while useful in theory, diet does not yield itself to a clearly defined intervention. As articulated earlier, diet is a continuous and dynamic exposure, and it is incredibly difficult to clearly define time zero; therefore, this hypothetical intervention is destined to be very ill-defined. However, the field of causal inference is progressing rapidly, and it is possible that new approaches will be devised to address ill-defined interventions. Finally, another direction for future research is estimating population attributable fractions and the burden of common mental disorders in adolescence attributable to poor diet.

Chapter 6

Conclusion

The results reported in four manuscripts that comprise this dissertation underscore the need for population-level prevention and health promotion programs that target multiple lifestyle behaviours, including the consumption of vegetables and fruit and sugar-sweetened beverages, to improve mental health in adolescents.

References

1. Glass TA, Goodman SN, Hernán MA, Samet JM. Causal inference in public health. *Annu Rev Public Health*. 2013;34:61–75.
2. Petitti DB. The implications of alternative views about causal inference for the work of the practising epidemiologist. Causal Inference, Epidemiological Resources, Inc, Chestnut Hill, MA. 1988;149–51.
3. Galea S, Hernán MA. Galea and Hernán respond to "Brings to the table," "Differential measurement error," and "Causal inference in social epidemiology." *Am J Epidemiol*. 2020;189(3):183–4.
4. Ferguson KD, McCann M, Katikireddi SV, Thomson H, Green MJ, Smith DJ, et al. Evidence synthesis for constructing directed acyclic graphs (ESC-DAGs): a novel and systematic method for building directed acyclic graphs. *Int J Epidemiol*. 2019;dyz220.
5. Robins JM, Hernán MA. Estimation of the causal effects of time-varying exposures. *Longitudinal data analysis*. 2009;553:599.
6. Jessor R, Jessor SL. Problem behavior and psychosocial development: a longitudinal study of youth. New York: Academic Press; 1977.
7. VanderWeele TJ, Ding P. Sensitivity analysis in observational research: introducing the E-value. *Ann Intern Med*. 2017;167(4):268–74.
8. Rockhill B. Theorizing about causes at the individual level while estimating effects at the population level: implications for prevention. *Epidemiology*. 2005;16(1):124–9.
9. Colman I, Ataullahjan A. Life course perspectives on the epidemiology of depression. *Can J Psychiatry*. 2010;55(10):622–32.
10. Jacka FN, Mykletun A, Berk M. Moving towards a population health approach to the primary prevention of common mental disorders. *BMC Med*. 2012 Dec;10(1).
11. Border R, Johnson EC, Evans LM, Smolen A, Berley N, Sullivan PF, et al. No support for historical candidate gene or candidate gene-by-interaction hypotheses for major depression across multiple large samples. *Am J Psychiatry*. 2019;176(5):376–87.
12. Evans GW, Li D, Whipple SS. Cumulative risk and child development. *Psychol Bull*. 2013;139(6):1342–96.
13. Nicolaou M, Colpo M, Vermeulen E, Elstgeest LEM, Cabout M, Gibson-Smith D, et al. Association of a priori dietary patterns with depressive symptoms: a harmonised meta-analysis of observational studies. *Psychol Med*. 2020;50(11):1872-83.
14. Firth J, Marx W, Dash S, Carney R, Teasdale SB, Solmi M, et al. The effects of dietary improvement on symptoms of depression and anxiety: a meta-analysis of randomized controlled trials. *Psychosom Med*. 2019;81(3):265–80.
15. Schuch FB, Vancampfort D, Firth J, Rosenbaum S, Ward PB, Silva ES, et al. Physical activity and incident depression: a meta-analysis of prospective cohort studies. *Am J Psychiatry*. 2018;175(7):631–48.
16. Zhang J, Yang SX, Wang L, Han LH, Wu XY. The influence of sedentary behaviour on mental health among children and adolescents: a systematic review and meta-analysis of longitudinal studies. *J Affect Disord*. 2022;306:90–114.
17. Gobbi G, Atkin T, Zytynski T, Wang S, Askari S, Boruff J, et al. Association of cannabis use in adolescence and risk of depression, anxiety, and suicidality in young adulthood. A systematic review and meta-analysis. *JAMA Psychiatry*. 2019;76(4):426–34.

18. Boaden K, Tomlinson A, Cortese S, Cipriani A. Antidepressants in children and adolescents: meta-review of efficacy, tolerability and suicidality in acute treatment. *Front Psychiatry*. 2020;11:717.
19. Bogl LH, Mehlig K, Ahrens W, Gwozdz W, de Henauw S, Molnár D, et al. Like me, like you – relative importance of peers and siblings on children's fast food consumption and screen time but not sports club participation depends on age. *Int J Behav Nutr Phys Act*. 2020;17(1):50.
20. Ragelienė T, Grønhøj A. The influence of peers′ and siblings′ on children's and adolescents′ healthy eating behavior. A systematic literature review. *Appetite*. 2020;148:104592.
21. Rose G. Sick individuals and sick populations. *Int J Epidemiol*. 2001;30(3):427–32.
22. Stelmach R, Kocher EL, Kataria I, Jackson-Morris AM, Saxena S, Nugent R. The global return on investment from preventing and treating adolescent mental disorders and suicide: a modelling study. *BMJ Global Health*. 2022;7(6):e007759.
23. Keyes K, Galea S. What matters most: quantifying an epidemiology of consequence. *Ann Epidemiol*. 2015;25(5):305–11.
24. Saxena S, Hosman C, Jané Llopis E, Organisation mondiale de la santé, Dept. of Mental Health and Substance Abuse, Prevention Research Centre (Pays-Bas). *Prevention of mental disorders: effective interventions and policy options: summary report*. Geneva, Switzerland: World Health Organization; 2004. https://apps.who.int/iris/bitstream/handle/10665/43027/924159215X_eng.pdf?sequence=1&isAllowed=y
25. Raine KD. Determinants of healthy eating in Canada: an overview and synthesis. *Can J Public Health*. 2005;96:S8–14.
26. Dawson SL, Dash SR, Jacka FN. The importance of diet and gut health to the treatment and prevention of mental disorders. In: *International Review of Neurobiology*. Elsevier; 2016. p. 325–46.
27. Jacobson MF, Krieger J, Brownell KD. Potential policy approaches to address diet-related diseases. *JAMA*. 2018;320(4):341–2.
28. Hernán MA. The C-word: scientific euphemisms do not improve causal inference from observational data. *Am J Public Health*. 2018;108(5):616–9.
29. Haber NA, Wieten SE, Rohrer JM, Arah OA, Tennant PWG, Stuart EA, et al. Causal and associational language in observational health research: a systematic evaluation. *Am J Epidemiol*. 2022;191(12):2084–97.
30. Wasserstein RL, Schirm AL, Lazar NA. Moving to a world beyond "p < 0.05." *Am Stat*. 2019;73(sup1):1–19.
31. Rothman KJ. Six persistent research misconceptions. *J Gen Intern Med*. 2014;29(7):1060–4.
32. Satija A, Stampfer MJ, Rimm EB, Willett W, Hu FB. Perspective: are large, simple trials the solution for nutrition research? *Adv Nutr*. 2018;9(4):378–87.
33. World Health Organization. *Healthy diet*. 2020. Geneva, Switzerland: World Health Organization; 2020. https://www.who.int/news-room/fact-sheets/detail/healthy-diet
34. Villiers A de, Faber M. Changing young people's food-related behaviour: a socio-ecological perspective. *Public Health Nutr*. 2019;22(11):1917–9.
35. Rong S, Liao Y, Zhou J, Yang W, Yang Y. Comparison of dietary guidelines among 96 countries worldwide. *Trends Food Sci Technol*. 2021;109:219–29.

36. Statistics Canada. *Change in total sugars consumption among Canadian children and adults*. 2019. https://www150.statcan.gc.ca/n1/pub/82-003-x/2019001/article/00002-eng.htm
37. Satija A, Yu E, Willett WC, Hu FB. Understanding nutritional epidemiology and its role in policy. *Adv Nutr*. 2015;6(1):5–18.
38. Freedman LS, Midthune D, Carroll RJ, Commins JM, Arab L, Baer DJ, et al. Application of a new statistical model for measurement error to the evaluation of dietary self-report instruments. *Epidemiology*. 2015;26(6):925–33.
39. Freedman LS, Schatzkin A, Midthune D, Kipnis V. Dealing with dietary measurement error in nutritional cohort studies. *J Natl Cancer Inst*. 2011;103(14):1086–92.
40. Reedy J, Subar AF, George SM, Krebs-Smith SM. Extending methods in dietary patterns research. *Nutrients*. 2018;10(5).
41. Willett W. *Nutritional epidemiology*. 3rd ed. Vol. 40. New York, NY: Oxford University Press; 2013. 529 p.
42. Subar AF, Freedman LS, Tooze JA, Kirkpatrick SI, Boushey C, Neuhouser ML, et al. Addressing current criticism regarding the value of self-report dietary data. *J Nutr*. 2015;145(12):2639–45.
43. Tomova GD, Arnold KF, Gilthorpe MS, Tennant PW. Adjustment for energy intake in nutritional research: a causal inference perspective. *Am J Clin Nutr*. 2022;115(1):189-98.
44. Hernán MA, Cole SR. Invited commentary: causal diagrams and measurement bias. *Am J Epidemiol*. 2009;170(8):959–62.
45. Beaton GH, Burema J, Ritenbaugh C. Errors in the interpretation of dietary assessments. *Am J Clin Nutr*. 1997;65(4 Suppl):1100S-1107S.
46. Haroz EE, Ybarra M, Eaton WW. Psychometric evaluation of a self-report scale to measure adolescent depression: the CESDR-10 in two national adolescent samples in the United States. *J Affect Disord*. 2014;158:154–60.
47. Tiirikainen K, Haravuori H, Ranta K, Kaltiala-Heino R, Marttunen M. Psychometric properties of the 7-item Generalized Anxiety Disorder Scale (GAD-7) in a large representative sample of Finnish adolescents. *Psychiatry Res*. 2019;272:30–5.
48. Shrier I, Platt RW. Reducing bias through directed acyclic graphs. *BMC Med Res Methodol*. 2008;8(1):70.
49. Tennant PW, Harrison WJ, Murray EJ, Arnold KF, Berrie L, Fox MP, et al. Use of directed acyclic graphs (DAGs) in applied health research: review and recommendations. *Int J Epidemiol*. 2021;50(2):620-32.
50. Haber NA, Wood ME, Wieten S, Breskin A. DAG With Omitted Objects Displayed (DAGWOOD): a framework for revealing causal assumptions in DAGs. *Ann Epidemiol*. 68:64–71.
51. Hernán MA, Robins JM. Estimating causal effects from epidemiological data. *J Epidemiol Community Health*. 2006;60(7):578–86.
52. Molendijk M, Molero P, Ortuno Sanchez-Pedreno F, Van der Does W, Angel Martinez-Gonzalez M. Diet quality and depression risk: a systematic review and dose-response meta-analysis of prospective studies. *J Affect Disord*. 2018;226:346–54.
53. Krieger N, Davey Smith G. The tale wagged by the DAG: broadening the scope of causal inference and explanation for epidemiology. *Int J Epidemiol*. 2016;45(6):1787–808.
54. Lawlor DA, Tilling K, Davey Smith G. Triangulation in aetiological epidemiology. *Int J Epidemiol*. 2016;45(6):1866–86.

Bibliography:

Afshin A, Sur PJ, Fay KA, Cornaby L, Ferrara G, Salama JS, et al. Health effects of dietary risks in 195 countries, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet*. 2019;393(10184):1958–72.

Alamian A, Paradis G. Clustering of chronic disease behavioral risk factors in Canadian children and adolescents. *Prev Med*. 2009;48(5):493–9.

Andresen EM, Malmgren JA, Carter WB, Patrick DL. Screening for depression in well older adults: evaluation of a short form of the CES-D (Center for Epidemiologic Studies Depression Scale). *Am J Prev Med*. 1994;10(2):77–84.

Angold A, Costello EJ. Depressive comorbidity in children and adolescents. *Am J Psychiatry*. 1993;150(12):1779–91.

Angold A, Costello EJ. Puberty and depression. *Child Adolesc Psychiatr Clin N Am*. 2006;15(4):919–37.

Appendix 7.5. Critical appraisal checklist for analytical cross-sectional studies - JBI Reviewer's Manual. https://wiki.joannabriggs.org/display/MANUAL/Appendix+7.5+Critical+appraisal+checklist+for+analytical+cross-sectional+studies

Arat G. Emerging protective and risk factors of mental health in Asian American students: findings from the 2013 Youth Risk Behavior Survey. *Vulnerable Child Youth Stud.* 2015;10(3):192–205.

Arat G. The link between nutrition and mental Health in Sub-Saharan African adolescents: findings from the Global School-Based Health Survey. *Glob Soc Welf*. 2017;4(1):31–40.

Arnett JJ. Emerging adulthood: a theory of development from the late teens through the twenties. *Am Psychol*. 2000;55(5):469–80.

Asare M. Sedentary behaviour and mental health in children and adolescents: a meta-analysis. *J Child Adolesc Behav*. 2015;3:259.

Barker M. Developmental origins, behaviour change and the new public health. *J Dev Orig Health Dis*. 2015;6(5):428–33.

Battista K, Qian W, Bredin C, Leatherdale ST. Student data linkage over multiple years. Technical Report Series. Waterloo, Ontario: University of Waterloo. 2019;6(3). https://uwaterloo.ca/compass-system/student-data-linkage-over-multiple-years.

Beaton GH, Burema J, Ritenbaugh C. Errors in the interpretation of dietary assessments. *Am J Clin Nutr*. 1997;65(4 Suppl):1100S-1107S.

Becker TD, Arnold MK, Ro V, Martin L, Rice TR. Systematic review of electronic cigarette use (vaping) and mental health comorbidity among adolescents and young adults. *Nicotine Tob Res*. 2021;23(3):415–25.

Berk M, Williams LJ, Jacka FN, O'Neil A, Pasco JA, Moylan S, et al. So depression is an inflammatory disease, but where does the inflammation come from? *BMC Medicine*. 2013;11:200.

Best O, Ban S. Adolescence: physical changes and neurological development. *Br J Nurs*. 2021;30(5):272–5.

Biddle SJH, Ciaccioni S, Thomas G, Vergeer I. Physical activity and mental health in children and adolescents: an updated review of reviews and an analysis of causality. *Psychol Sport Exerc*. 2019;42:146–55.

Biddle SJH, Pearson N, Ross GM, Braithwaite R. Tracking of sedentary behaviours of young people: a systematic review. *Prev Med*. 2010;51(5):345–51.

Boaden K, Tomlinson A, Cortese S, Cipriani A. Antidepressants in children and adolescents: meta-review of efficacy, tolerability and suicidality in acute treatment. *Front Psychiatry*. 2020;11:717.

Bogl LH, Mehlig K, Ahrens W, Gwozdz W, de Henauw S, Molnár D, et al. Like me, like you – relative importance of peers and siblings on children's fast food consumption and screen time but not sports club participation depends on age. *Int J Behav Nutr Phys Act*. 2020;17(1):50.

Bono C, Ried LD, Kimberlin C, Vogel B. Missing data on the Center for Epidemiologic Studies Depression Scale: a comparison of 4 imputation techniques. *Res Social Adm Pharm*. 2007 Mar;3(1):1–27.

Border R, Johnson EC, Evans LM, Smolen A, Berley N, Sullivan PF, et al. No support for historical candidate gene or candidate gene-by-interaction hypotheses for major depression across multiple large samples. *Am J Psychiatry*. 2019;176(5):376–87.

Bradley KL, Bagnell AL, Brannen CL. Factorial validity of the Center for Epidemiological Studies Depression 10 in adolescents. *Issues Ment Health Nurs*. 2010;31(6):408–12.

Brambila-Macias J, Shankar B, Capacci S, Mazzocchi M, Perez-Cueto FJ, Verbeke W, et al. Policy interventions to promote healthy eating: a review of what works, what does not, and what is promising. *Food Nutr Bull*. 2011;32(4):365–75.

Breslau J, Gilman SE, Stein BD, Ruder T, Gmelin T, Miller E. Sex differences in recent first-onset depression in an epidemiological sample of adolescents. *Transl Psychiatry*. 2017;7(5):e1139.

Buchan MC, Romano I, Butler A, Laxer RE, Patte KA, Leatherdale ST. Bi-directional relationships between physical activity and mental health among a large sample of Canadian

youth: a sex-stratified analysis of students in the COMPASS study. *Int J Behav Nutr Phys Act*. 2021;18(1):132.

Burns KE, Vermeer J, Battista K, Leatherdale ST. A School-level examination of the association between programs and policies and physical activity outcomes among females from the COMPASS Study. *Int J Environ Res Public Health*. 2021;18(6):3314.

Busch J, Claus C, Schneider S, Siefen RG. Does a lower self-concept contribute to mental health disparities of diverse immigrant youth from middle childhood to late adolescence? *BMC Psychol*. 2021;9(1):1–14.

Caine-Bish NL, Scheule B. Gender differences in food preferences of school-aged children and adolescents. *J Sch Health*. 2009;79(11):532–40.

Cairns KE, Yap MBH, Pilkington PD, Jorm AF. Risk and protective factors for depression that adolescents can modify: a systematic review and meta-analysis of longitudinal studies. *J Affect Disord*. 2014;169:61–75.

Canadian Institute for Health Information. *Care for children and youth with mental disorders*. 2015. https://secure.cihi.ca/estore/productFamily.htm?locale=en&pf=PFC2866.

Canadian Institute for Health Information. *Children and youth mental health in Canada*. 2022. https://www.cihi.ca/en/children-and-youth-mental-health-in-canada.

Canadian Mental Health Association. *Fast facts about mental health and mental illness*. Canadian Mental Health Association; 2021. https://cmha.ca/brochure/fast-facts-about-mental-illness/

Canadian Mental Health Association. *Mental illnesses in children and youth.* 2014. https://cmha.bc.ca/documents/mental-illnesses-in-children-and-youth-2/

Canadian Paediatric Society. *A proposal to increase taxes on sugar-sweetened beverages in Canada*. Canadian Paediatric Society. 2020. https://cps.ca/en/documents/position/tax-on-sugar-sweetened-beverages

Canadian Public Health Association. *A public health approach to population mental wellness.* Ottawa, Canada: Canadian Public Health Association; 2021. https://www.cpha.ca/public-health-approach-population-mental-wellness

Canadian Public Health Association. *Review of Canada's initial response to the COVID-19 pandemic*. Ottawa, Canada: Canadian Public Health Association; 2021. https://www.cpha.ca/review-canadas-initial-response-covid-19-pandemic

Canadian Public Health Association. *Tobacco and vaping use in Canada: moving forward*. 2021. https://www.cpha.ca/tobacco-and-vaping-use-canada-moving-forward.

Bibliography

Champion KE, Mather M, Spring B, Kay-Lambkin F, Teesson M, Newton NC. Clustering of multiple risk behaviors among a sample of 18-year-old Australians and associations with mental health outcomes: a latent class analysis. *Front Public Health*. 2018;6(101616579):135.

Cipriani A, Zhou X, Del Giovane C, Hetrick SE, Qin B, Whittington C, et al. Comparative efficacy and tolerability of antidepressants for major depressive disorder in children and adolescents: a network meta-analysis. *Lancet*. 2016;388(10047):881–90.

Clayborne ZM, Varin M, Colman I. Systematic review and meta-analysis: adolescent depression and long-term psychosocial outcomes. *J Am Acad Child Adolesc Psychiatry*. 2019;58(1):72–9.

Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ*. 2000;320(7244):1240-3.

Colman I, Ataullahjan A. Life course perspectives on the epidemiology of depression. *Can J Psychiatry*. 2010;55(10):622–32.

Colman I, Naicker K, Zeng Y, Ataullahjan A, Senthilselvan A, Patten SB. Predictors of long-term prognosis of depression. *CMAJ.* 2011;183(17):1969–76.

Compton MT, Shim RS. Mental illness prevention and mental health promotion: when, who, and how. *Psychiatr Serv.* 2020;71(9):981-3.

Cummins KM, Marks C. Farewell to bright-line: a guide to reporting quantitative results without the S-word. *Front Psychol*. 2020;doi:10.3389/fpsyg.2020.00815

Dabravolskaj J, Khan MKA, Veugelers PJ, Maximova K. Mental health and wellbeing of 9-12-year-old children in Northern Canada before the Covid-19 pandemic and after the first lockdown. *Int J Public Health*. 2021;1:1604219.

Dawson SL, Dash SR, Jacka FN. The importance of diet and gut health to the treatment and prevention of mental disorders. In: *International Review of Neurobiology*. Elsevier; 2016. p. 325–46.

Deraspe R. *Current issues in mental health in Canada: the economic impact of mental illness (in brief).* Library of Parliament, Ottawa, Canada; 2013. https://publications.gc.ca/collections/collection_2018/bdp-lop/eb/YM32-5-2013-87-eng.pdf

deRuiter WK, Cairney J, Leatherdale S, Faulkner G. The period prevalence of risk behavior co-occurrence among Canadians. *Prev Med*. 2016;85:11–6.

Diener E, Wirtz D, Tov W, et al. New well-being measures: short scales to assess flourishing and positive and negative feelings. *Soc Indic Res*. 2010;97(2):143–56.

Downey RG, King C. Missing data in Likert ratings: A comparison of replacement methods. *J Gen Psychol*. 1998 Apr;125(2):175–91.

Doyle YG, Furey A, Flowers J. Sick individuals and sick populations: 20 years later. *J Epidemiol Community Health*. 2006 May;60(5):396–8.

Dreher ML. Whole fruits and fruit fiber emerging health effects. *Nutrients*. 2018;10(12):1833.

Drug Free Kids Canada. *Youth and alcohol*. https://www.drugfreekidscanada.org/wp-content/uploads/2019/10/DFK_Info_YouthAlcohol_FINAL.pdf.

Drug Free Kids Canada. *Vaping*. https://www.drugfreekidscanada.org/prevention/issues/vaping/.

Esteban-Gonzalo L, Turner AI, Torres SJ, Esteban-Cornejo I, Castro-Pinero J, Delgado-Alfonso A, et al. Diet quality and well-being in children and adolescents: the UP&DOWN longitudinal study. *Br J Nutr*. 2019;121(2):221–31.

Evans GW, Li D, Whipple SS. Cumulative risk and child development. *Psychol Bull*. 2013;139(6):1342–96.

Fenwick-Smith A, Dahlberg EE, Thompson SC. Systematic review of resilience-enhancing, universal, primary school-based mental health promotion programs. *BMC Psychol*. 2018;6(1):30.

Ferguson KD, McCann M, Katikireddi SV, Thomson H, Green MJ, Smith DJ, et al. Evidence synthesis for constructing directed acyclic graphs (ESC-DAGs): a novel and systematic method for building directed acyclic graphs. *Int J Epidemiol*. 2019;dyz220.

Fergusson DM, Boden JM, Horwood LJ. Tests of causal links between alcohol abuse or dependence and major depression. *Arch Gen Psychiatry*. 2009;66(3):260–6.

Firth J, Marx W, Dash S, Carney R, Teasdale SB, Solmi M, et al. The effects of dietary improvement on symptoms of depression and anxiety: a meta-analysis of randomized controlled trials. *Psychosom Med*. 2019;81(3):265–80.

Freedman LS, Midthune D, Carroll RJ, Commins JM, Arab L, Baer DJ, et al. Application of a new statistical model for measurement error to the evaluation of dietary self-report instruments. *Epidemiology*. 2015;26(6):925–33.

Freedman LS, Schatzkin A, Midthune D, Kipnis V. Dealing with dietary measurement error in nutritional cohort studies. *J Natl Cancer Inst*. 2011;103(14):1086–92.

Fuhrmann D, Knoll LJ, Blakemore SJ. Adolescence as a sensitive period of brain development. *Trends Cogn Sci*. 2015;19(10):558–66.

Galea S, Hernán MA. Galea and Hernán respond to "Brings to the table," "Differential measurement error," and "Causal inference in social epidemiology." *Am J Epidemiol*. 2020;189(3):183–4.

Gardner LA, Champion KE, Grummitt L, Chapman C, Sunderland M, Thornton L, et al. Clustering of six key risk behaviors for chronic disease among adolescent females. *Int J Environ Res Public Health*. 2020;17(19):1–12.

Gardner W, Pajer K, Cloutier P, et al. Changing rates of self-harm and mental disorders by sex in youths presenting to Ontario emergency departments: repeated cross-sectional study. *Can J Psychiatry*. 2019;64(11):789–97.

Garriguet D. Diet quality in Canada. *Health Rep.* 2009;20(3):41–52.

Gassman-Pines A, Ananat EO, Fitz-Henley J 2nd. COVID-19 and parent-child psychological well-being. *Pediatrics*. 2020;146(4):e2020007294.

Georgiades K, Duncan L, Wang L, Comeau J, Boyle MH. Six-month prevalence of mental disorders and service contacts among children and youth in Ontario: evidence from the 2014 Ontario Child Health Study. *Can J Psychiatry*. 2019;64(4):246–55.

Glass TA, Goodman SN, Hernán MA, Samet JM. Causal inference in public health. *Annu Rev Public Health*. 2013;34:61–75.

Gobbi G, Atkin T, Zytynski T, Wang S, Askari S, Boruff J, et al. Association of cannabis use in adolescence and risk of depression, anxiety, and suicidality in young adulthood. A systematic review and meta-analysis. *JAMA Psychiatry*. 2019;76(4):426–34.

Godin KM, Chaurasia A, Hammond D, Leatherdale ST. Food purchasing behaviors and sugar-sweetened beverage consumption among Canadian secondary school students in the COMPASS Study. *J Nutr Educ Behav*. 2018;50(8):803-12.

Gong G, He Y, Evans AC. Brain connectivity: gender makes a difference. *Neuroscientist*. 2011;17(5):575–91.

Government of Canada. *The human face of mental health and mental illness in Canada*. Government of Canada; 2006. https://www.phac-aspc.gc.ca/publicat/human-humain06/pdf/human_face_e.pdf

Greenland S. Quality scores are useless and potentially misleading. *Am J Epidemiol.* 1994;140(3):300–1.

Haber NA, Wieten SE, Rohrer JM, Arah OA, Tennant PWG, Stuart EA, et al. Causal and associational language in observational health research: a systematic evaluation. *Am J Epidemiol*. 2022;191(12):2084–97.

Haber NA, Wood ME, Wieten S, Breskin A. DAG With Omitted Objects Displayed (DAGWOOD): a framework for revealing causal assumptions in DAGs. *Ann Epidemiol*. 68:64–71.

Haroz EE, Ybarra M, Eaton WW. Psychometric evaluation of a self-report scale to measure adolescent depression: the CESDR-10 in two national adolescent samples in the United States. *J Affect Disord*. 2014;158:154–60.

Haye K de la, D'Amico EJ, Miles JNV, Ewing B, Tucker JS. Covariance among multiple health risk behaviors in adolescents. *PLOS One*. 2014;9(5):e98141.

Hayward J, Jacka FN, Skouteris H, Millar L, Strugnell C, Swinburn BA, et al. Lifestyle factors and adolescent depressive symptomatology: associations and effect sizes of diet, physical activity and sedentary behaviour. *Aust N Z J Psychiatry*. 2016;50(11):1064–73.

Health Canada. *Canada's Food Guide*. 2021. https://www.canada.ca/en/health-canada/services/canada-food-guides.html.

Health Canada. *Eating Well with Canada's Food Guide*. 2011. https://www.canada.ca/content/dam/hc-sc/migration/hc-sc/fn-an/alt_formats/hpfb-dgpsa/pdf/food-guide-aliment/print_eatwell_bienmang-eng.pdf. Accessed 22 Sep 2019.

Health Canada. *Section 2: Foods and beverages that undermine healthy eating. Canada Food Guide*. 2022. https://food-guide.canada.ca/en/guidelines/section-2-foods-and-beverages-undermine-healthy-eating/

Health Canada. *Smoking, vaping and tobacco*. 2015. https://www.canada.ca/en/health-canada/services/smoking-tobacco.html.

Health Canada. *Summary of results for the Canadian Student Tobacco, Alcohol and Drugs Survey 2018-19*. 2022. https://www.canada.ca/en/health-canada/services/canadian-student-tobacco-alcohol-drugs-survey/2018-2019-summary.html

Hernán MA, Cole SR. Invited commentary: causal diagrams and measurement bias. *Am J Epidemiol*. 2009;170(8):959–62.

Hernán MA, Robins JM. Estimating causal effects from epidemiological data. *J Epidemiol Community Health*. 2006;60(7):578–86.

Hernán MA. The C-word: scientific euphemisms do not improve causal inference from observational data. *Am J Public Health*. 2018;108(5):616–9.

Hoare E, Hockey M, Ruusunen A, Jacka FN. Does fruit and vegetable consumption during adolescence predict adult depression? A longitudinal study of US adolescents. *Front Psychiatry*. 2018;9:581.

Hoare E, Marx W, Firth J, McLeod S, Jacka F, Chrousos GP, et al. Lifestyle behavioural risk factors and emotional functioning among schoolchildren: The Healthy Growth Study. *Eur Psychiatry J Assoc Eur Psychiatr*. 2019;61:79–84.

Hoare E, Millar L, Fuller-Tyszkiewicz M, Skouteris H, Nichols M, Jacka F, et al. Associations between obesogenic risk and depressive symptomatology in Australian adolescents: a cross-sectional study. *J Epidemiol Community Health.* 2014;68(8):767–72.

Hoare E, Millar L, Fuller-Tyszkiewicz M, Skouteris H, Nichols M, Malakellis M, et al. Depressive symptomatology, weight status and obesogenic risk among Australian adolescents: a prospective cohort study. *BMJ Open*. 2016;6(3):e010072.

Hong SA, Peltzer K. Dietary behaviour, psychological well-being and mental distress among adolescents in Korea. *Child Adolesc Psychiatry Ment Health*. 2017;11(101297974):56.

Hopkins K, Crosland P, Elliott N, Bewley S. Diagnosis and management of depression in children and young people: summary of updated NICE guidance. *Br J Sports Med*. 2016;50(3):184–6.

Hox J. Multilevel analysis: techniques and applications (Reprint. ed.) Erlbaum. Mahwah, NJ: Erlbaum; 2002.

Hu D, Cheng L, Jiang W. Sugar-sweetened beverages consumption and the risk of depression: A meta-analysis of observational studies. *J Affect Disord*. 2019;245:348-55.

Hu FB, Malik VS. Sugar-sweetened beverages and risk of obesity and type 2 diabetes: epidemiologic evidence. *Physiol Behav*. 2010;100(1):47–54.

Hu MX, Turner D, Generaal E, Bos D, Ikram MK, Ikram MA, et al. Exercise interventions for the prevention of depression: a systematic review of meta-analyses. *BMC Public Health*. 2020;20(1):1255.

Hyde JS, Mezulis AH, Abramson LY. The ABCs of depression: integrating affective, biological, and cognitive models to explain the emergence of the gender difference in depression. *Psychol Rev*. 2008;115(2):291-313.

Ioannidis JP. We need more randomized trials in nutrition—preferably large, long-term, and with negative results. *Am J Clin Nutr*. 2016;103(6):1385–6.

Ipsos. *Public perspectives: 3rd annual Canadian mental health check-up*. 2017. https://www.ipsos.com/sites/default/files/2017-08/IpsosPA_PublicPerspectives_CA_April%202017%20Mental%20Health.pdf

Jacka FN, Kremer PJ, Berk M, et al. A prospective study of diet quality and mental health in adolescents. *PloS One*. 2011;6(9):e24805.

Jacka FN, Mykletun A, Berk M. Moving towards a population health approach to the primary prevention of common mental disorders. *BMC Med*. 2012 Dec;10(1).

Jacka FN, Rothon C, Taylor S, Berk M, Stansfeld SA. Diet quality and mental health problems in adolescents from East London: a prospective study. *Soc Psychiatry Psychiatr Epidemiol*. 2013;48(8):1297–306.

Jacobson MF, Krieger J, Brownell KD. Potential policy approaches to address diet-related diseases. *JAMA*. 2018;320(4):341–2.

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

Johnson D, Dupuis G, Piche J, Clayborne Z, Colman I. Adult mental health outcomes of adolescent depression: a systematic review. *Depress Anxiety*. 2018;35(8):700–16.

Jones DS, Podolsky SH. The history and fate of the gold standard. *Lancet*. 2015;385(9977):1502–3.

Keller KL, Kling SMR, Fuchs B, Pearce AL, Reigh NA, Masterson T, et al. A biopsychosocial model of sex differences in children's eating behaviors. *Nutrients*. 2019;11(3):682.

Kelly Y, Zilanawala A, Booker C, Sacker A. Social media use and adolescent mental health: findings from the UK Millennium Cohort Study. *EClinicalMedicine*. 2018;6:59–68.

Kessler RC, Berglund P, Demler O, Jin R, Merikangas KR, Walters EE. Lifetime prevalence and age-of-onset distributions of DSM-IV disorders in the National Comorbidity Survey Replication. *Arch Gen Psychiatry*. 2005;62(6):593–602.

Kessler RC, Bromet EJ. The epidemiology of depression across cultures. *Annu Rev Public Health*. 2013;34:119–38.

Keyes K, Galea S. What matters most: quantifying an epidemiology of consequence. *Ann Epidemiol*. 2015;25(5):305–11.

Khalid S, Williams CM, Reynolds SA. Is there an association between diet and depression in children and adolescents? A systematic review. *Br J Nutr*. 2016;116(12):2097–108.

Kim TH, Choi J young, Lee HH, Park Y. Associations between dietary pattern and depression in Korean adolescent girls. *J Pediatr Adolesc Gynecol*. 2015;28(6):533–7.

Kim YK, Shin C. The microbiota-gut-brain axis in neuropsychiatric disorders: pathophysiological mechanisms and novel treatments. *Curr Neuropharmacol*. 2018;16(5):559–73.

Kleppang AL, Haugland SH, Bakken A, Stea TH. Lifestyle habits and depressive symptoms in Norwegian adolescents: a national cross-sectional study. *BMC Public Health*. 2021;21(1):816.

Krieger N, Davey Smith G. The tale wagged by the DAG: broadening the scope of causal inference and explanation for epidemiology. *Int J Epidemiol*. 2016;45(6):1787–808.

Krieger N. Theories for social epidemiology in the 21st century: an ecosocial perspective. *Int J Epidemiol*. 2001;30(4):668–77.

Lake AA, Mathers JC, Rugg-Gunn AJ, Adamson AJ. Longitudinal change in food habits between adolescence (11–12 years) and adulthood (32–33 years): the ASH30 Study. *J Public Health*. 2006;28(1):10–6.

Lassale C, Batty GD, Baghdadli A, Jacka F, Sánchez-Villegas A, Kivimäki M, et al. Healthy dietary indices and risk of depressive outcomes: a systematic review and meta-analysis of observational studies. *Mol Psychiatry*. 2018;24(7):965–86.

Lawlor DA, Tilling K, Davey Smith G. Triangulation in aetiological epidemiology. *Int J Epidemiol*. 2016;45(6):1866–86.

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;17:102.

Le LKD, Esturas AC, Mihalopoulos C, Chiotelis O, Bucholc J, Chatterton ML, et al. Cost-effectiveness evidence of mental health prevention and promotion interventions: a systematic review of economic evaluations. *PLoS Med*. 2021;18(5):e1003606.

Leatherdale S, Laxer RE, Faulkner G. *Reliability and validity of the physical activity and sedentary behaviour measures in the COMPASS study*. COMPASS Technical Report Series. Waterloo, Ontario: University of Waterloo. 2014;2(1). https://uwaterloo.ca/compass-system/publications/reliability-and-validity-physical-activity-and-sedentary.

Leatherdale ST, Brown KS, Carson V, Childs RA, Dubin JA, Elliott SJ, 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 Apr 8;14:331.

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;10:42.

Lim KL, Jacobs P, Ohinmaa A, Schopflocher D, Dewa CS. A new population-based measure of the economic burden of mental illness in Canada. *Chronic Dis Can.* 2008;28(3):92–8.

Liu MW, Chen QT, Towne SD, Zhang J, Yu HJ, Tang R, et al. Fruit and vegetable intake in relation to depressive and anxiety symptoms among adolescents in 25 low- and middle-income countries. *J Affect Disord*. 2020;261:172–80.

Liu S, Munasinghe LL, Maximova K, Taylor JP, Ohinmaa A, Veugelers PJ. The economic burden of excessive sugar consumption in Canada: should the scope of preventive action be broadened? *Can J Public Health*. 2022;113(3):331–40.

Liu X, Yan Y, Li F, Zhang D. Fruit and vegetable consumption and the risk of depression: A meta-analysis. *Nutrition*. 2016;32(3):296–302.

Loewen OK, Maximova K, Ekwaru JP, Faught EL, Asbridge M, Ohinmaa A, et al. Lifestyle behavior and mental health in early adolescence. *Pediatrics*. 2019;143(5):e20183307.

Loughman A, Ponsonby AL, O'Hely M, Symeonides C, Collier F, Tang ML, et al. Gut microbiota composition during infancy and subsequent behavioural outcomes. *EBioMedicine*. 2020;52:102640.

Lovato N, Gradisar M. A meta-analysis and model of the relationship between sleep and depression in adolescents: recommendations for future research and clinical practice. *Sleep Med Rev*. 2014;18(6):521–9.

Lukomskyj N, Allman-Farinelli M, Shi Y, Rangan A. Dietary exposures in childhood and adulthood and cardiometabolic outcomes: a systematic scoping review. *J Hum Nutr Diet*. 2021;34(3):511–23.

Marsh HW. SDQ II manual: self description questionnaire - II. Campbelltown, N.S.W.: University of Western Sydney, Macarthur; 1990.

Marx W, Lane M, Hockey M, Aslam H, Berk M, Walder K, et al. Diet and depression: exploring the biological mechanisms of action. *Mol Psychiatry*. 2021;26(1):134–50.

Mathur MB, Ding P, Riddell CA, VanderWeele TJ. Web Site and R Package for Computing E-values. *Epidemiology*. 2018;29(5):e45–7.

Maximova K, Khan M, Dabravolskaj J, Maunula L, Ohinmaa A, Veugelers P. Perceived changes in lifestyle behaviours and in mental health and wellbeing of elementary school children during the first COVID-19 lockdown in Canada. *Public Health*. 2021;202:35-42.

McDaid D, Park AL, Wahlbeck K. The economic case for the prevention of mental illness. *Annu Rev Public Health.* 2019;40(1):373–89.

McMartin SE, Kuhle S, Colman I, Kirk SF, Veugelers PJ. Diet quality and mental health in subsequent years among Canadian youth. *Public Health Nutr*. 2012;15(12):2253–8.

McMartin SE, Kuhle S, Colman I, Kirk SF, Veugelers PJ. Diet quality and mental health in subsequent years among Canadian youth. *Public Health Nutr*. 2012;15(12):2253–8.

McMurray RG, Ward DS, Elder JP, Lytle LA, Strikmiller PK, Baggett CD, et al. Do overweight girls overreport physical activity? *Am J Health Behav*. 2008;32(5):538–46.

Mendelson T, Eaton WW. Recent advances in the prevention of mental disorders. *Soc Psychiatry Psychiatr Epidemiol*. 2018;53(4):325–39.

Mental Health Commission of Canada. *Changing directions, changing lives: the mental health strategy for Canada*. Calgary: Mental Health Commission of Canada; 2012. https://central.bac-lac.gc.ca/.item?id=Strategy_Document&op=pdf&app=Library

Mental Health Commission of Canada. *Making the case for investing in mental health in Canada*. Mental Health Commission of Canada; 2016. https://www.mentalhealthcommission.ca/sites/default/files/2016-06/Investing_in_Mental_Health_FINAL_Version_ENG.pdf

Mental Health Commission of Canada. *Toward recovery and well-being: a framework for a mental health strategy for Canada*. Mental Health Commission of Canada; 2009. https://www.mentalhealthcommission.ca/wp-content/uploads/drupal/FNIM_Toward_Recovery_and_Well_Being_ENG_0_1.pdf

Merikangas KR, He JP, Burstein M, Swanson SA, Avenevoli S, Cui L, et al. Lifetime prevalence of mental disorders in US adolescents: results from the National Comorbidity Study-Adolescent Supplement (NCS-A). *J Am Acad Child Adolesc Psychiatry*. 2010;49(10):980–9.

Merikangas KR, Nakamura EF, Kessler RC. Epidemiology of mental disorders in children and adolescents. *Dialogues Clin Neurosci*. 2009;11(1):7–20.

Methods for linking COMPASS student-level data over time. COMPASS System. 2015. https://uwaterloo.ca/compass-system/publications/methods-linking-compass-student-level-data-over-time

Molendijk M, Molero P, Ortuno Sanchez-Pedreno F, Van der Does W, Angel Martinez-Gonzalez M. Diet quality and depression risk: a systematic review and dose-response meta-analysis of prospective studies. *J Affect Disord*. 2018;226:346–54.

Molendijk ML, Molero P, Thomas-Odenthal F, van der Does W. There is not much to mediate [yet] when it comes to diet and depression. *Mol Psychiatry*. 2022;27(2):776–7.

Molteni R, Barnard RJ, Ying Z, Roberts CK, Gómez-Pinilla F. A high-fat, refined sugar diet reduces hippocampal brain-derived neurotrophic factor, neuronal plasticity, and learning. *Neuroscience*. 2002;112(4):803–14.

Narmandakh A, Roest AM, de Jonge P, Oldehinkel AJ. Psychosocial and biological risk factors of anxiety disorders in adolescents: a TRAILS report. *Eur Child Adolesc Psychiatry*. 2021;30(12):1969–82.

National Institute of Mental Health. *Mental illness definitions*. 2022. https://www.nimh.nih.gov/health/statistics/mental-illness.shtml

Nguyen B, Ding D, Mihrshahi S. Fruit and vegetable consumption and psychological distress: cross-sectional and longitudinal analyses based on a large Australian sample. *BMJ Open*. 2017;15;7(3):e014201.

Nicolaou M, Colpo M, Vermeulen E, Elstgeest LEM, Cabout M, Gibson-Smith D, et al. Association of a priori dietary patterns with depressive symptoms: a harmonised meta-analysis of observational studies. *Psychol Med*. 2020;50(11):1872-83.

O'Neil A, Jacka FN, Quirk SE, Cocker F, Taylor CB, Oldenburg B, et al. A shared framework for the common mental disorders and non-communicable disease: key considerations for disease prevention and control. *BMC Psychiatry*. 2015;15:15.

O'Neil A, Quirk SE, Housden S, Brennan SL, Williams LJ, Pasco JA, et al. Relationship between diet and mental health in children and adolescents: a systematic review. *Am J Public Health*. 2014;104(10):e31–42.

Orlando L, Savel KA, Madigan S, Colasanto M, Korczak DJ. Dietary patterns and internalizing symptoms in children and adolescents: a meta-analysis. *Aust N Z J Psychiatry*. 2021;00048674211031486.

Pampalon R, Raymond G. A deprivation index for health and welfare planning in Quebec. *Chronic Dis Can*. 2000;21(3):104–13.

Park S, Rim SJ, Lee JH. Associations between dietary behaviours and perceived physical and mental health status among Korean adolescents. *Nutr Diet J Dietit Assoc Aust*. 2018;75(5):488–93.

Petitti DB. The implications of alternative views about causal inference for the work of the practising epidemiologist. Causal Inference, Epidemiological Resources, Inc, Chestnut Hill, MA. 1988;149–51.

Polanczyk GV, Salum GA, Sugaya LS, Caye A, Rohde LA. Annual research review: a meta-analysis of the worldwide prevalence of mental disorders in children and adolescents. *J Child Psychol Psychiatry*. 2015;56(3):345–65.

Public Health Agency of Canada. *Report from the Canadian Chronic Disease Surveillance System: mental illness in Canada.* 2015. https://www.canada.ca/en/public-health/services/publications/diseases-conditions/report-canadian-chronic-disease-surveillance-system-mental-illness-canada-2015.html#s1a

Racine N, McArthur BA, Cooke JE, Eirich R, Zhu J, Madigan S. Global prevalence of depressive and anxiety symptoms in children and adolescents during Covid-19: a meta-analysis. *JAMA Pediatr*. 2021;175(11):1142–50.

Radez J, Reardon T, Creswell C, Lawrence PJ, Evdoka-Burton G, Waite P. Why do children and adolescents (not) seek and access professional help for their mental health problems? A systematic review of quantitative and qualitative studies. *Eur Child Adolesc Psychiatry*. 2021;30(2):183–211.

Ragelienė T, Grønhøj A. The influence of peers′ and siblings′ on children's and adolescents′ healthy eating behavior. A systematic literature review. *Appetite*. 2020;148:104592.

Raine KD. Determinants of healthy eating in Canada: an overview and synthesis. *Can J Public Health*. 2005;96:S8–14.

Reedy J, Subar AF, George SM, Krebs-Smith SM. Extending methods in dietary patterns research. *Nutrients*. 2018;10(5).

Robins JM, Hernán MA. Estimation of the causal effects of time-varying exposures. *Longitudinal data analysis*. 2009;553:599.

Rockhill B. Theorizing about causes at the individual level while estimating effects at the population level: implications for prevention. *Epidemiology*. 2005;16(1):124–9.

Romano I, Ferro MA, Patte KA, Leatherdale ST. Measurement invariance of the GAD-7 and CESD-R-10 among adolescents in Canada. *J Pediatr Psychol*. 2022;47(5):585–94.

Rong S, Liao Y, Zhou J, Yang W, Yang Y. Comparison of dietary guidelines among 96 countries worldwide. *Trends Food Sci Technol*. 2021;109:219–29.

Rose G. Sick individuals and sick populations. *Int J Epidemiol*. 2001;30(3):427–32.

Rosen L, Manor O, Engelhard D, Zucker D. In defense of the randomized controlled trial for health promotion research. *Am J Public Health*. 2006;96(7):1181–6.

Rothman KJ, Greenland S, Lash TL. Modern epidemiology. Vol. 3. Wolters Kluwer Health, Lippincott Williams & Wilkins Philadelphia. 2008.

Rothman KJ. Six persistent research misconceptions. *J Gen Intern Med*. 2014;29(7):1060–4.

Saghafian F, Malmir H, Saneei P, Milajerdi A, Larijani B, Esmaillzadeh A. Fruit and vegetable consumption and risk of depression: accumulative evidence from an updated systematic review and meta-analysis of epidemiological studies. *Br J Nutr*. 2018;119(10):1087–101.

Sampasa-Kanyinga H, Chaput JP, Goldfield GS, Janssen I, Wang J, Hamilton HA, et al. 24-hour movement guidelines and suicidality among adolescents. *J Affect Disord*. 2020;274:372–80.

Satija A, Stampfer MJ, Rimm EB, Willett W, Hu FB. Perspective: are large, simple trials the solution for nutrition research? *Adv Nutr*. 2018;9(4):378–87.

Satija A, Yu E, Willett WC, Hu FB. Understanding nutritional epidemiology and its role in policy. *Adv Nutr*. 2015;6(1):5–18.

Saxena S, Hosman C, Jané Llopis E, Organisation mondiale de la santé, Dept. of Mental Health and Substance Abuse, Prevention Research Centre (Pays-Bas). *Prevention of mental disorders: effective interventions and policy options: summary report*. Geneva, Switzerland: World Health Organization; 2004. https://apps.who.int/iris/bitstream/handle/10665/43027/924159215X_eng.pdf?sequence=1&isAllowed=y

Schuch FB, Vancampfort D, Firth J, Rosenbaum S, Ward PB, Silva ES, et al. Physical activity and incident depression: a meta-analysis of prospective cohort studies. *Am J Psychiatry*. 2018;175(7):631–48.

Shrier I, Platt RW. Reducing bias through directed acyclic graphs. *BMC Med Res Methodol*. 2008;8(1):70.

SickKids. *COVID-19: guidance for school operation during the pandemic.* SickKids. 2021. https://www.sickkids.ca/en/news/archive/2021/covid19_updated_guidance_school_operation-during-pandemic/

Smetanin P, Stiff D, Briante C, Adair CE, Ahmad S, Khan M. *The life and economic impact of major mental illnesses in Canada.* Toronto, ON: RiskAnalytica, on behalf of the Mental Health Commission of Canada; 2011. https://www.mentalhealthcommission.ca/sites/default/files/MHCC_Report_Base_Case_FINAL_ENG_0_0.pdf

Spitzer RL, Kroenke K, Williams JBW, Löwe B. A brief measure for assessing generalized anxiety disorder: the GAD-7. *Arch Intern Med*. 2006;166(10):1092–7.

Spring B, Moller AC, Coons MJ. Multiple health behaviours: overview and implications. *J Public Health*. 2012;34(Suppl 1):i3–10.

StataCorp. Stata Statistical Software: Release 17. College Station, TX: StataCorp LLC; 2021.

Statistics Canada. Added, free and total sugar content and consumption of foods and beverages in Canada. 2020. https://www150.statcan.gc.ca/n1/pub/82-003-x/2020010/article/00002-eng.htm

Statistics Canada. *Census Profile, 2016 Census*. 2017. https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/index.cfm?Lang=E.

Statistics Canada. *Change in total sugars consumption among Canadian children and adults*. 2019. https://www150.statcan.gc.ca/n1/pub/82-003-x/2019001/article/00002-eng.htm

Statistics Canada. *Correlates of vaping among adolescents in Canada*. 2022. https://www150.statcan.gc.ca/n1/pub/82-003-x/2022007/article/00003-eng.htm.

Statistics Canada. *Labour market impacts of COVID-19 on Indigenous people: March to August 2020*. 2020. https://www150.statcan.gc.ca/n1/pub/45-28-0001/2020001/article/00085-eng.htm

Stelmach R, Kocher EL, Kataria I, Jackson-Morris AM, Saxena S, Nugent R. The global return on investment from preventing and treating adolescent mental disorders and suicide: a modelling study. *BMJ Global Health*. 2022;7(6):e007759.

Subar AF, Freedman LS, Tooze JA, Kirkpatrick SI, Boushey C, Neuhouser ML, et al. Addressing current criticism regarding the value of self-report dietary data. *J Nutr*. 2015;145(12):2639–45.

Taylor AM, Holscher HD. A review of dietary and microbial connections to depression, anxiety, and stress. *Nutr Neurosci*. 2020;23(3):237-250.

Telama R. Tracking of physical activity from childhood to adulthood: a review. *Obes Facts*. 2009;2(3):187–95.

Tennant PW, Harrison WJ, Murray EJ, Arnold KF, Berrie L, Fox MP, et al. Use of directed acyclic graphs (DAGs) in applied health research: review and recommendations. *Int J Epidemiol*. 2021;50(2):620-32.

Tennant PW, Murray EJ, Arnold KF, Berrie L, Fox MP, Gadd SC, et al. Use of directed acyclic graphs (DAGs) to identify confounders in applied health research: review and recommendations. *Int J Epidemiol*. 2021;50(2):620-32.

Textor J, van der Zander B, Gilthorpe MS, Liskiewicz M, Ellison GT. Robust causal inference using directed acyclic graphs: the R package "dagitty." *Int J Epidemiol*. 2016;45(6):1887–94.

Thapar A, Collishaw S, Pine DS, Thapar AK. Depression in adolescence. *Lancet*. 2012;379(9820):1056–67.

Thomas-Odenthal F, Molero P, van der Does W, Molendijk M. Impact of review method on the conclusions of clinical reviews: a systematic review on dietary interventions in depression as a case in point. *PLOS One*. 2020;15(9):e0238131.

Thompson-Haile A, Bredin C, Leatherdale ST. Rationale for using an active information passive-consent permission protocol. Waterloo: University of Waterloo; COMPASS Technical Report Series, vol.1, 2013. https://uwaterloo.ca/compass-system/publications/rationale-using-active-information-passive-consent

Tiirikainen K, Haravuori H, Ranta K, Kaltiala-Heino R, Marttunen M. Psychometric properties of the 7-item Generalized Anxiety Disorder Scale (GAD-7) in a large representative sample of Finnish adolescents. *Psychiatry Res*. 2019;272:30–5.

Tomova GD, Arnold KF, Gilthorpe MS, Tennant PW. Adjustment for energy intake in nutritional research: a causal inference perspective. *Am J Clin Nutr*. 2022;115(1):189-98.

Tremblay MS, Carson V, Chaput JP, Connor Gorber S, Dinh T, Duggan M, 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.

Umberson D, Crosnoe R, Reczek C. Social relationships and health behavior across life course. *Annu Rev Sociol*. 2010;36:139–57.

United Nations News. *The end of the COVID-19 pandemic is in sight: WHO*. 2022. https://news.un.org/en/story/2022/09/1126621

VanderWeele TJ, Ding P. Sensitivity analysis in observational research: introducing the E-value. *Ann Intern Med*. 2017;167(4):268–74.

Veritas Health Innovation. *Covidence systematic review software*. Melbourne, Australia

Vermeulen MCM, van der Heijden KB, Kocevska D, Treur JL, Huppertz C, van Beijsterveldt CEM, et al. Associations of sleep with psychological problems and well-being in adolescence: causality or common genetic predispositions? *J Child Psychol Psychiatry*. 2021;62:28–39.

Veugelers PJ, Taylor JP, Ohinmaa A, Liu S, Munasinghe LL, Maximova K. To tax or not to tax? That's the sugar-coated question. *Can J Public Health*. 2022;113(5):786-7.

Vigo D, Thornicroft G, Atun R. Estimating the true global burden of mental illness. *Lancet Psychiatry*. 2016:3(2):171–8.

Villiers A de, Faber M. Changing young people's food-related behaviour: a socio-ecological perspective. *Public Health Nutr*. 2019;22(11):1917–9.

Viner RM, Ross D, Hardy R, Kuh D, Power C, Johnson A, et al. Life course epidemiology: recognising the importance of adolescence. *J Epidemiol Community Health*. 2015;69(8):719–20.

Wang J, Shao L, Sun X, Young L. Increased oxidative stress in the anterior cingulate cortex of subjects with bipolar disorder and schizophrenia. *Bipolar Disord*. 2009;11(5):523–9.

Wasserstein RL, Schirm AL, Lazar NA. Moving to a world beyond "p<0.05." *Am Stat*. 2019;73(sup1):1–19.

Wells GA, Shea B, O'Connell D, Peterson J, Welch V, Losos M, et al. The Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses (2008). http://www.ohri.ca/programs/clinical_epidemiology/oxford.asp

Wiens K, Bhattarai A, Pedram P, Dores A, Williams J, Bulloch A, et al. A growing need for youth mental health services in Canada: examining trends in youth mental health from 2011 to 2018. *Epidemiol Psychiatr Sci*. 2020;29:e115.

Wiens K, Williams JVA, Lavorato DH, et al. Is the prevalence of major depression increasing in the Canadian adolescent population? Assessing trends from 2000 to 2014. *J Affect Disord*. 2017;210:22–6.

Willett W. *Nutritional epidemiology*. 3rd ed. Vol. 40. New York, NY: Oxford University Press; 2013. 529 p.

Wilson J, Blizzard L, Gall S, et al. Youth diet quality and hazard of mood disorder in adolescence and adulthood among an Australian cohort. *J Affect Disord*. 2020;276:511-8.

Winpenny EM, van Harmelen AL, White M, van Sluijs EMF, Goodyer IM. Diet quality and depressive symptoms in adolescence: no cross-sectional or prospective associations following adjustment for covariates. *Public Health Nutr*. 2018;21(13):2376–84.

Woolf SH. Potential health and economic consequences of misplaced priorities. *JAMA*. 2007;297(5):523–6.

World Health Organization. *Fruit and vegetables for health. Report of a Joint FAO/WHO Workshop*. Kobe, Japan: World Health Organization; 2004. http://www.fao.org/3/a-y5861e.pdf

World Health Organization. *Global burden of mental disorders and the need for a comprehensive, coordinated response from health and social sectors at the country level*. Geneva, Switzerland: World Health Organization; 2012. https://apps.who.int/iris/bitstream/handle/10665/78898/A65_10-en.pdf?sequence=1&isAllowed=y

World Health Organization. *Healthy diet*. 2020. Geneva, Switzerland: World Health Organization; 2020. https://www.who.int/news-room/fact-sheets/detail/healthy-diet

World Health Organization. *Investing in mental health: evidence for action*. Geneva, Switzerland: World Health Organization; 2013. https://apps.who.int/iris/bitstream/handle/10665/87232/9789241564618_eng.pdf?sequence=1

World Health Organization. *Mental disorders*. Geneva, Switzerland: World Health Organization; 2022. https://www.who.int/news-room/fact-sheets/detail/mental-disorders

World Health Organization. *Mental health: a state of well-being*. Geneva, Switzerland: World Health Organization; 2022. https://www.who.int/features/factfiles/mental_health/en/

World Health Organization. *WHO manual on sugar-sweetened beverage taxation policies to promote healthy diets*. Geneva, Switzerland: World Health Organization; 2022 https://www.who.int/publications-detail-redirect/9789240056299

Wu X, Bastian K, Ohinmaa A, Veugelers P. Influence of physical activity, sedentary behavior, and diet quality in childhood on the incidence of internalizing and externalizing disorders during adolescence: a population-based cohort study. *Ann Epidemiol*. 2018;28(2):86–94.

Zhang J, Yang SX, Wang L, Han LH, Wu XY. The influence of sedentary behaviour on mental health among children and adolescents: a systematic review and meta-analysis of longitudinal studies. *J Affect Disord*. 2022;306:90–114.

Appendices

Appendix A

The search strategies use two filters, which were adapted for each database:

Campbell S. A filter to retrieve studies related to fruits from the OVID MEDLINE Database. John W. Scott Health Sciences Library, University of Alberta. Rev. Oct 7, 2019. https://docs.google.com/document/d/1S2AtLS76jaJxK0Pi_UOThdbXZYQiaO1WKddIOj4hLpE/edit

Campbell S. A filter to retrieve studies related to vegetables from the OVID MEDLINE Database. John W. Scott Health Sciences Library, University of Alberta. Rev. Oct 10, 2019. https://docs.google.com/document/d/19vrxZwZ5QHp030Ic55WUm6thtMdvM_tjBs7FrG3EJXM/edit

Ovid MEDLINE(R) ALL <1946 to October 30, 2020>

#	Search Statement	Results
1	*Fruit/	21758
2	("high fiber" or "high fibre" or "dietary fiber" or "dietary fibre" or FRUIT or fruits or ACAI or ACKEE or "ACTINIDIA ARGUTA" or "AIELE FRUIT*" or AMLA or (APPLE* not (phone* or computer* or smartphone* or device*)) or APRICOTS or apricot or ARONIA or avocado* or BABACO or BACURI or "BAEL FRUIT" or BANANA* or BERRIES or Blueberries or barberr* or brambleberr* or BREADFRUIT or BUSH BUTTER or "CACTUS PEAR* ORCAJA" or "CAMU CAMU" or clementines or GOOSEBERRIES or CARAMBOLAS or "CASHEW APPLE*" or CHERIMOYA or CHERRIES or "CHERRY LAUREL" or CITRUS or ORANGES or CITRONS or nectarine* or TAMURANA or currants or Dragonfruit* or GALGALS or grapes or GRAPEFRUIT* or "KI MIKAN" or KUMQUAT* or LEMONS or lemons or LIMES or lingonberr* or ORTANIQUE or POMELOS or TANGELO or TANGOR or YUZU or COCONA or CUPUACU or "CURCULIGO LATIFOLIA ORDATES" or DURIAN or FEIJOA or FIGS or FORTUNELLA or GUAVAS or HAWTHORN or JABOTICABA or "JAK FRUITS" or "JELLY FIGS" or KIWANO or KIWIFRUIT or "kiwi fruit*" or LANGSAT or LITCHIS or LONGANS or LOQUATS or MAMEY or MANGOES or MANGOSTEENS or MARULA or MEDLARS or medlar or MELON or melons or CANTALOUPE* or HONEYDEW or MUSKMELONS or MYROBALANS or MYRTLE or NARANJILLA or NONI or OLIVES or OMIJA or PAPAYAS or "PASSION FRUIT*" or passionfruit* or PEACHES or peach or PEARS or PEPINO or PERSIMMON* or PHALSA or PINEAPPLE* or PITAYOS or PLUMS or plum or POMEGRANATE* or "PRICKLY PEAR*" or prune or prunes or	169251

	QUINCE or quinces or RAMBUTAN or rhubarb or rockmelon* or raspberr* or ROSEHIP* or SAPODILLA* or SASKATOONS or "saskatoon berr*" or "SEA BUCKTHORN*" or SLOES or SOURSOP or SPONDIAS or STARfruit* or strawberr* or tangerine* or tangelo* or TAMARIND* or TOMATILLO* or TOMATO* or WATERMELON* or EGUSI or bearberr* or soapberr* or salmonberr* or crowberr* or huckleberr* or haskap or cranberr* or chokecherr* or pincherr* or cloudberr* or dewberr* or elderberr* or "partridge berr*").ti,ab.	
3	*Vegetables/	12846
4	vegetable*.ti,ab.	53185
5	(Artichoke* or arugula or Asparagus or aubergine* or "bamboo shoot*" or basil or bean or beans or beet or beets or beetroot* or "bok choy" or broadbean* or broccoflower or broccoli or "brussel* sprout*" or cabbage* or caraway or carrot* or cauliflower* or capsicum* or celeriac or celery* or chickpea* or chives or cilantro or collard* or coriander or corn or courgette* or cucumber* or daikon or edemame or eggplant* or endive or endives or fennel or fiddlehead* or garbanzos or garlic or ginger or greens or jimcama or kale or kohlrabi or leek* or legume* or lentil or lentils or lettuce* or okra or onion* or oregano or peas or parsley or parsnip* or pepper* or potato* or pumpkin* or radish* or radicchio or rutabaga* or salad or salads or salsify or scallion* or shallot* or sorrel or soybean* or spinach or squash or sweetcorn or "Swiss chard" or taro or tomatillo or topinambur or turnip* or "water chestnut*" or watercress or yam or yams or zucchini*).ti,ab.	197952
6	1or 2 or 3 or 4 o4 5	367920
7	Anxiety/ or *Mental Health/	98344
8	hypervigilance.ti,ab.	676
9	anxiety disorders/ or agoraphobia/ or anxiety, separation/ or neurocirculatory asthenia/ or neurotic disorders/ or obsessive-compulsive disorder/ or hoarding disorder/ or panic disorder/ or phobic disorders/ or phobia, social/	77949
10	anxiety.ti,ab.	180274
11	agoraphobia.ti,ab.	3012
12	neurocirculatory asthenia.ti,ab.	264
13	neurotic disorder*.ti,ab.	806
14	Depression/	114471
15	depressive disorder/ or depressive disorder, major/ or dysthymic disorder/ or seasonal affective disorder/	101154
16	depressive.ti,ab.	111053
17	depression.ti,ab.	319066
18	dysthymic disorder*.ti,ab.	766
19	("seasonal affective disorder*" or "internali?ing symptoms" or "common mental disorders" or cmd or cmds).ti,ab.	6855
20	7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19	574885
21	6 and 20	2362
22	limit 21 to ("child (6 to 12 years)" or "adolescent (13 to 18 years)")	258

23	limit 21 to ("newborn infant (birth to 1 month)" or "infant (1 to 23 months)" or "preschool child (2 to 5 years)" or "all adult (19 plus years)")	720
24	22 and 23	175
25	(21 not 23) or 24	1817
26	(youth or youths or adolescen* or teen* or high school* or middle school* or tween or tweens or young people or pubescent or pubescence or pre-pubescen*).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]	2109818
27	21 and 26	255
28	25 or 27	1825
29	exp Laboratory Animals/ or exp Disease Models, Animal/ or (rat or rats or mouse or mice or rabbit* or cat or cats or dog or dogs or pig or pigs or piglet* or procine or canine or rodent* or feline* or sheep or ewe or lamb or goat or goats or cow or cows or cattle or bovine or horse or horses or equine or fish or fishes or "Afar Depression" or "Great Depression" or "inbreeding depression" or "orange fluorescence" or "MdPI depression" or "respiratory depression" or "fruit bat*" or duck or ducks or bird or birds or turkey* or chicken* or insect* or "fruit fly" or "mito* depression" or aromatherapy or "Agent Orange" or "Orange County" or Cherry Valley or "Medlars Service").mp.	5431331
30	28 not 29	792
31	remove duplicates from 30	788

Embase OVID<1974 to 2020 October 30>

#	**Search Statement**	**Results**
1	exp *Fruit/ or "fruit vegetable"/	45785
2	("high fiber" or "high fibre" or "dietary fiber" or "dietary fibre" or FRUIT or fruits or ACAI or ACKEE or "ACTINIDIA ARGUTA" or "AIELE FRUIT*" or AMLA or (APPLE* not (phone* or computer* or smartphone* or device*)) or APRICOTS or apricot or ARONIA or avocado* or BABACO or BACURI or "BAEL FRUIT" or BANANA* or BERRIES or Blueberries or barberr* or brambleberr* or BREADFRUIT or BUSH BUTTER or "CACTUS PEAR*" or CAJA or "CAMU CAMU" or clementines or GOOSEBERRIES or CARAMBOLAS or "CASHEW APPLE*" or CHERIMOYA or CHERRIES or "CHERRY LAUREL" or CITRUS or ORANGES or CITRONS or nectarine* or TAMURANA or currants or Dragonfruit* or GALGALS or grapes or GRAPEFRUIT* or "KI MIKAN" or KUMQUAT* or LEMONS or lemons or LIMES or lingonberr* or	193922

	ORTANIQUE or POMELOS or TANGELO or TANGOR or YUZU or COCONA or CUPUACU or "CURCULIGO LATIFOLIA" or DURIAN or FEIJOA or FORTUNELLA or GUAVAS or HAWTHORN or JABOTICABA or "JAK FRUITS" or "JELLY FIGS" or KIWANO or KIWIFRUIT or "kiwi fruit*" or LANGSAT or LITCHIS or LONGANS or LOQUATS or MAMEY or MANGOES or MANGOSTEENS or MARULA or MEDLARS or medlar or MELON or melons or CANTALOUPE* or HONEYDEW or MUSKMELONS or MYROBALANS or MYRTLE or NARANJILLA or NONI or OLIVES or OMIJA or PAPAYAS or "PASSION FRUIT*" or passionfruit* or PEACHES or peach or PEARS or PEPINO or PERSIMMON* or PHALSA or PINEAPPLE* or PITAYOS or PLUMS or plum or POMEGRANATE* or "PRICKLY PEAR*" or prune or prunes or QUINCE or quinces or RAMBUTAN or rhubarb or rockmelon* or raspberr* or ROSEHIP* or SAPODILLA* or SASKATOONS or "saskatoon berr*" or "SEA BUCKTHORN*" or SLOES or SOURSOP or SPONDIAS or STARfruit* or strawberr* or tangerine* or tangelo* or TAMARIND* or TOMATILLO* or TOMATO* or WATERMELON* or EGUSI or bearberr* or soapberr* or salmonberr* or crowberr* or huckleberr* or haskap or cranberr* or chokecherr* or pincherr* or cloudberr* or dewberr* or elderberr* or "partridge berr*").ti,ab.	
3	exp *Vegetable/	73915
4	vegetable*.ti,ab.	66674
5	(Artichoke* or arugula or Asparagus or aubergine* or "bamboo shoot*" or basil or bean or beans or beet or beets or beetroot* or "bok choy" or broadbean* or broccoflower or broccoli or "brussel* sprout*" or cabbage* or caraway or carrot* or cauliflower* or capsicum* or celeriac or celery* or chickpea* or chives or cilantro or collard* or coriander or corn or courgette* or cucumber* or daikon or edemame or eggplant* or endive or endives or fennel or fiddlehead* or garbanzos or garlic or ginger or greens or jimcama or kale or kohlrabi or leek* or legume* or lentil or lentils or lettuce* or okra or onion* or oregano or peas or parsley or parsnip* or pepper* or potato* or pumpkin* or radish* or radicchio or rutabaga* or sage or salad or salads or salsify or scallion* or shallot* or sorrel or soybean* or spinach or squash or sweetcorn or "Swiss chard" or taro or tomatillo or topinambur or turnip* or "water chestnut*" or watercress or yam or yams or zucchini*).ti,ab.	222984
6	1 or 2 or 3 or 4 or 5	444131
7	anxiety/ or mental health/ or psychological well-being/	328780
8	hypervigilance.ti,ab.	960
9	anxiety disorder/ or generalized anxiety disorder/ or "mixed anxiety and depression"/	75307
10	anxiety.ti,ab.	259621
11	agoraphobia.ti,ab.	3984

12	neurocirculatory asthenia.mp.	162
13	neurotic disorder*.mp.	1224
14	depression/ or adolescent depression/ or atypical depression/ or chronic depression/ or dysphoria/ or dysthymia/ or major depression/ or minor depression/ or "mixed anxiety and depression"/ or seasonal affective disorder/	411982
15	depressive disorder*.ti,ab.	47762
16	dysthymic disorder*.ti,ab.	969
17	("seasonal affective disorder*" or "common mental disorders" or cmd or cmds).ti,ab.	6652
18	7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17	745785
19	6 and 18	4290
20	(youth or youths or adolescen* or teen* or high school* or middle school* or tween or tweens or young people or pubescent or pubescence or pre-pubescen*).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]	1659610
21	limit 19 to (adult <18 to 64 years> or aged <65+ years>)	2080
22	19	4290
23	limit 19 to (embryo <first trimester> or infant <to one year> or child <unspecified age> or preschool child <1 to 6 years>)	387
24	21 or 23	2357
25	limit 24 to (school child <7 to 12 years> or adolescent <13 to 17 years>)	372
26	19 not 24	1933
27	25 or 26	2305
28	19 and 20	621
29	27 or 28	2366
30	exp animal experiment/ or exp animal model/ or exp animal disease/ or (animal* or rat or rats or mouse or mice or rabbit* or cat or cats or dog or dogs or pig or pigs or piglet* or procine or canine or rodent* or feline* or sheep or ewe or lamb or goat or goats or cow or cows or cattle or bison* or buffalo* bovine or horse or horses or equine or fish or fishes or "Afar Depression" or "Great Depression" or "inbreeding depression" or "orange fluorescence" or "MdPI depression" or "fruit bat*" or duck or ducks or bird or birds or turkey* or chicken* or insect* or "fruit fly" or "mito* depression" or aromatherapy or "Agent Orange" or "Orange County" or Cherry Valley or "Medlars Service" or dementia* or alzheimer* or "sage publication*").mp.	7253684
31	29 not 30	968
32	remove duplicates from 31	960

PsycINFO OVID <1806 to October 30 2020>

#	Search Statement	**Results**
1	(fruit or fruits).ti,ab. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures, mesh]	8832
2	("high fiber" or "high fibre" or "dietary fiber" or "dietary fibre" or FRUIT or fruits or ACAI or ACKEE or "ACTINIDIA ARGUTA" or "AIELE FRUIT*" or AMLA or (APPLE* not (phone* or computer* or smartphone* or device*)) or APRICOTS or apricot or ARONIA or avocado* or BABACO or BACURI or "BAEL FRUIT" or BANANA* or BERRIES or Blueberries or barberr* or brambleberr* or BREADFRUIT or BUSH BUTTER or "CACTUS PEAR*" or CAJA or "CAMU CAMU" or clementines or GOOSEBERRIES or CARAMBOLAS or "CASHEW APPLE*" or CHERIMOYA or CHERRIES or "CHERRY LAUREL" or CITRUS or ORANGES or CITRONS or nectarine* or TAMURANA or currants or Dragonfruit* or GALGALS or grapes or GRAPEFRUIT* or "KI MIKAN" or KUMQUAT* or LEMONS or lemons or LIMES or lingonberr* or ORTANIQUE or POMELOS or TANGELO or TANGOR or YUZU or COCONA or CUPUACU or "CURCULIGO LATIFOLIA" or DURIAN or FEIJOA or FORTUNELLA or GUAVAS or HAWTHORN or JABOTICABA or "JAK FRUITS" or "JELLY FIGS" or KIWANO or KIWIFRUIT or "kiwi fruit*" or LANGSAT or LITCHIS or LONGANS or LOQUATS or MAMEY or MANGOES or MANGOSTEENS or MARULA or MEDLARS or medlar or MELON or melons or CANTALOUPE* or HONEYDEW or MUSKMELONS or MYROBALANS or MYRTLE or NARANJILLA or NONI or OLIVES or OMIJA or PAPAYAS or "PASSION FRUIT*" or passionfruit* or PEACHES or peach or PEARS or PEPINO or PERSIMMON* or PHALSA or PINEAPPLE* or PITAYOS or PLUMS or plum or POMEGRANATE* or "PRICKLY PEAR*" or prune or prunes or QUINCE or quinces or RAMBUTAN or rhubarb or rockmelon* or raspberr* or ROSEHIP* or SAPODILLA* or SASKATOONS or "saskatoon berr*" or "SEA BUCKTHORN*" or SLOES or SOURSOP or SPONDIAS or STARfruit* or strawberr* or tangerine* or tangelo* or TAMARIND* or TOMATILLO* or TOMATO* or WATERMELON* or EGUSI or bearberr* or soapberr* or salmonberr* or crowberr* or huckleberr* or haskap or cranberr* or chokecherr* or pincherr* or cloudberr* or dewberr* or elderberr* or "partridge berr*").ti,ab.	13299
3	vegetable*.ti,ab.	5753
4	(Artichoke* or arugula or Asparagus or aubergine* or "bamboo shoot*" or basil or bean or beans or beet or beets or beetroot* or "bok choy" or broadbean* or broccoflower or broccoli or "brussel* sprout*" or cabbage* or caraway or carrot* or cauliflower* or capsicum* or celeriac or celery* or chickpea* or chives or cilantro or collard* or coriander or corn or courgette* or cucumber* or daikon or edemame or eggplant* or endive or endives or fennel or fiddlehead* or garbanzos	5852

	or garlic or ginger or greens or jimcama or kale or kohlrabi or leek* or legume* or lentil or lentils or lettuce* or okra or onion* or oregano or peas or parsley or parsnip* or pepper* or potato* or pumpkin* or radish* or radicchio or rutabaga* or salad or salads or salsify or scallion* or shallot* or sorrel or soybean* or spinach or squash or sweetcorn or "Swiss chard" or taro or tomatillo or topinambur or turnip* or "water chestnut*" or watercress or yam or yams or zucchini*).ti,ab.	
5	1 or 2 or 3 or 4	19567
6	Anxiety/	59895
7	hypervigilance.mp.	856
8	anxiety disorders/ or generalized anxiety disorder/ or internalizing symptoms/	21251
9	anxiety.mp.	228158
10	agoraphobia.mp.	5659
11	neurocirculatory asthenia.mp.	135
12	neurotic disorder*.mp.	7327
13	"depression (emotion)"/	25292
14	major depression/ or dysthymic disorder/ or atypical depression/ or internalizing symptoms/ or seasonal affective disorder/ or mental health/ or primary mental health prevention/	182269
15	depressive.mp.	106924
16	(depression or ("common mental disorders" or cmd or cmds)).mp.	321309
17	dysthymic disorder*.mp.	2517
18	"seasonal affective disorder*".mp.	1579
19	6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18	520128
20	5 and 19	988
21	limit 20 to (120 neonatal <birth to age 1 mo> or 140 infancy <2 to 23 mo> or 160 preschool age <age 2 to 5 yrs>)	23
22	20	988
23	limit 22 to "300 adulthood <age 18 yrs and older>"	490
24	21 or 23	502
25	limit 24 to (180 school age <age 6 to 12 yrs> or 200 adolescence <age 13 to 17 yrs>)	49
26	(20 not 24) or 25	535
27	20 and (youth or youths or adolescen* or teen* or high school* or middle school* or tween or tweens or young people or pubescent or pubescence or pre-pubescen*).mp.	164
28	26 or 27	589
29	exp Animal Models/ or (animal* or rat or rats or mouse or mice or rabbit* or cat or cats or dog or dogs or pig or pigs or piglet* or procine or canine or rodent* or feline* or sheep or ewe or lamb or goat or goats or cow or cows or cattle or bison* or buffalo* bovine or horse or horses or equine or fish or fishes or "Afar Depression" or "Great Depression" or "inbreeding depression" or "orange fluorescence" or	609390

	"MdPI depression" or "fruit bat*" or duck or ducks or bird or birds or turkey* or chicken* or insect* or "fruit fly" or "mito* depression" or aromatherapy or "Agent Orange" or "Orange County" or Cherry Valley or "Medlars Service" or dementia* or alzheimer*).mp. or ("older adult*" or elderly).ti.	
30	28 not 29	419
31	remove duplicates from 30	419

FSTA (WOS) Timespan=All Searched October 30, 2020

S1	DESCRIPTORS: (FRUITS OR ACAI OR ACKEE OR ACTINIDIA ARGUTA OR AIELE FRUITS OR AMLA OR APPLES OR APRICOTS OR ARONIA OR BABACO OR BACURI OR BAEL FRUIT OR BANANAS OR BARBADOS CHERRIES OR BERRIES OR BREADFRUIT OR BUSH BUTTER OR CACTI OR CACTUS PEARS OR CAJA OR CAMU-CAMU OR CAPE GOOSEBERRIES OR CARAMBOLAS OR CASHEW APPLES OR CHERIMOYA OR CHERRIES OR CHERRY LAUREL OR CITRUS FRUITS OR COCONA OR CORNELIAN CHERRIES OR CUPUACU OR CURCULIGO LATIFOLIA OR CUSTARD APPLES OR DATES OR DURIAN OR EXOTIC FRUITS OR FEIJOA OR FIGS OR FORTUNELLA OR GUAVAS OR HAWTHORN FRUITS OR JABOTICABA OR JAK FRUITS OR JAPANESE APRICOTS OR JELLY FIGS OR JUJUBES OR KIWANO OR KIWIFRUIT OR LANGSAT OR LITCHIS OR LONGANS OR LOQUATS OR MALAY APPLES OR MAMEY OR MANGOES OR MANGOSTEENS OR MARULA OR MEDLARS OR MELONS OR MYROBALANS OR MYRTLE OR NARANJILLA OR NONI OR OLIVES OR OMIJA OR PAPAYAS OR PASSION FRUITS OR PEACHES OR PEARS OR PEPINO OR PERSIMMONS OR PHALSA OR PINEAPPLES OR PITAYOS OR PLUMS OR POME FRUITS OR POMEGRANATES OR PRICKLY PEARS OR QUINCES OR RAMBUTAN OR ROSE APPLES OR ROSEHIPS OR SAPODILLAS OR SASKATOON FRUITS OR SEA BUCKTHORN OR SLOES OR SOURSOP OR SPONDIAS OR STAR APPLES OR STONE FRUITS OR SUGAR APPLES OR TAMARILLOS OR TAMARINDS OR TOMATILLOS OR TOMATOES OR TROPICAL FRUITS OR WATERMELONS OR WILD FRUITS) OR TOPIC: (("high fiber" or "high fibre" or "dietary fiber" or "dietary fibre" or FRUIT or fruits or ACAI or ACKEE or "ACTINIDIA ARGUTA" or "AIELE FRUIT*" or AMLA or (APPLE* not (phone* or computer* or smartphone* or device*)) or APRICOTS or apricot or ARONIA or avocado* or BABACO or BACURI or "BAEL FRUIT" or BANANA* or BERRIES or Blueberries or barberr* or brambleberr* or BREADFRUIT or BUSH BUTTER or "CACTUS PEAR*" or CAJA or	466,913

	"CAMU CAMU" or clementines or GOOSEBERRIES or CARAMBOLAS or "CASHEW APPLE*" or CHERIMOYA or CHERRIES or "CHERRY LAUREL" or CITRUS or ORANGES or CITRONS or nectarine* or TAMURANA or currants or Dragonfruit* or GALGALS or grapes or GRAPEFRUIT* or "KI MIKAN" or KUMQUAT* or LEMONS or lemons or LIMES or lingonberr* or ORTANIQUE or POMELOS or TANGELO or TANGOR or YUZU or COCONA or CUPUACU or "CURCULIGO LATIFOLIA" or DURIAN or FEIJOA or FORTUNELLA or GUAVAS or HAWTHORN or JABOTICABA or "JAK FRUITS" or "JELLY FIGS" or KIWANO or KIWIFRUIT or "kiwi fruit*" or LANGSAT or LITCHIS or LONGANS or LOQUATS or MAMEY or MANGOES or MANGOSTEENS or MARULA or MEDLARS or medlar or MELON or melons or CANTALOUPE* or HONEYDEW or MUSKMELONS or MYROBALANS or MYRTLE or NARANJILLA or NONI or OLIVES or OMIJA or PAPAYAS or "PASSION FRUIT*" or passionfruit* or PEACHES or peach or PEARS or PEPINO or PERSIMMON* or PHALSA or PINEAPPLE* or PITAYOS or PLUMS or plum or POMEGRANATE* or "PRICKLY PEAR*" or prune or prunes or QUINCE or quinces or RAMBUTAN or rhubarb or rockmelon* or raspberr* or ROSEHIP* or SAPODILLA* or SASKATOONS or "saskatoon berr*" or "SEA BUCKTHORN*" or SLOES or SOURSOP or SPONDIAS or STARfruit* or strawberr* or tangerine* or tangelo* or TAMARIND* or TOMATILLO* or TOMATO* or WATERMELON* or EGUSI or bearberr* or soapberr* or salmonberr* or crowberr* or huckleberr* or haskap or cranberr* or chokecherr* or pincherr* or cloudberr* or dewberr* or elderberr* or "partridge berr*")) OR TOPIC: ((Artichoke* or arugula or Asparagus or aubergine* or "bamboo shoot*" or basil or bean or beans or beet or beets or beetroot* or "bok choy" or broadbean* or broccoflower or broccoli or "brussel* sprout*" or cabbage* or caraway or carrot* or cauliflower* or capsicum* or celeriac or celery* or chickpea* or chives or cilantro or collard* or coriander or corn or courgette* or cucumber* or daikon or edemame or eggplant* or endive or endives or fennel or fiddlehead* or garbanzos or garlic or ginger or greens or jimcama or kale or kohlrabi or leek* or legume* or lentil or lentils or lettuce* or okra or onion* or oregano or peas or parsley or parsnip* or pepper* or potato* or pumpkin* or radish* or radicchio or rutabaga* or salad or salads or salsify or scallion* or shallot* or sorrel or soybean* or spinach or squash or sweetcorn or "Swiss chard" or taro or tomatillo or topinambur or turnip* or "water chestnut*" or watercress or yam or yams or zucchini* or vegetable*)) OR DESCRIPTORS: (VEGETABLES OR DRIED PEAS OR DRIED VEGETABLES OR VEGETABLES SPECIFIC OR ALLIUM OR AMARANTH LEAVES OR ANU OR ARRACACHA OR ARROWHEAD OR ARTICHOKES OR ASPARAGUS OR AUBERGINES OR AVOCADOS OR	

	BAMBOO OR BAOBAB OR BEETS OR BITTER LEAF OR BLACK SALSIFY OR BORAGE OR BOXTHORN OR BRASSICA OR BROCCOLI OR BRUSSELS SPROUTS OR BURDOCK OR BUTTERBUR OR CABBAGES OR CANNA OR CAPSICUMS OR CARDOONS OR CARROTS OR CASSAVA OR CAULIFLOWERS OR CELERIAC OR CELERY OR CEYLON SPINACH OR CHAYOTE OR CHICORY (VEGETABLES) OR CHINESE CABBAGES OR CHINESE CHIVES OR CHINESE WATER CHESTNUTS OR CHUFA NUTS OR COCOYAMS OR CORCHORUS OLITORIUS OR COURGETTES OR CRESS OR CRUCIFERAE OR CUCUMBERS OR CUCURBITACEAE OR CURCUMA OR DANDELIONS OR EDIBLE FLOWERS OR ELEPHANT YAMS OR ENDIVES OR ERUCA SATIVA OR EWEDU OR EXOTIC VEGETABLES OR FENNEL OR FENUGREEK OR FUNGI EDIBLE OR GHERKINS OR GLOBE ARTICHOKES OR GODULBAEGI OR GOURDS OR GREEN VEGETABLES OR HOUTTUYNIA CORDATA OR INDIAN SPINACH OR JERUSALEM ARTICHOKES OR KALE OR KOHLRABI OR KOMATSUNA OR KUDZU OR LEAFY VEGETABLES OR LEEKS OR LEGUMES OR LETTUCES OR LILY BULBS OR LOTUS ROOTS OR MACA OR MARROWS OR MUSTARD GREENS OR NETTLES OR OCA OR OKRA OR ONIONS OR PALM HEARTS OR PARSNIPS OR PERILLA OR POTATOES OR PUMPKINS OR PURSLANE OR RADISHES OR RAKKYO OR RHUBARB OR ROCKET OR ROOT CROPS OR ROOT VEGETABLES OR SALAD VEGETABLES OR SALSIFY OR SCALLION OR SEA KALE OR SESBANIA OR SHALLOTS OR SOLANUM OR SPINACH OR SPROUTS OR SQUASHES OR SWEDES OR SWEET POTATOES OR SWEETCORN OR SWISS CHARD OR TUBERS OR TURNIPS OR ULLUCO OR VINE LEAVES OR WATER CHESTNUTS OR WATER DROPWORT OR WATER SPINACH OR WATERCRESS OR WELSH ONIONS OR WILD CABBAGE OR WILD VEGETABLES OR YACON OR YAMS OR ZEDOARY)	
S2	DESCRIPTORS: (DEPRESSION) OR TOPIC: ("neurotic disorder" or hypervigilance or agoraphobia or "dysthymic disorder" or anxiety or "common mental disorders" or cmd or "internalizing symptoms" or "internalising symptoms") OR TOPIC: ("mental illness" or "clinical depression" or "major depression" or "mental health")	3,226
S3	#1 and #2	546
S4	DESCRIPTORS: (ANIMAL MODELS OR ANIMAL DISEASES)	43,239
S5	TS=(animal* or rat or rats or mouse or mice or rabbit* or cat or cats or dog or dogs or pig or pigs or piglet* or procine or canine or rodent* or feline* or sheep or ewe or lamb or goat or goats or cow or cows or cattle or bison* or buffalo* bovine or horse or horses or equine or fish or fishes or"Afar Depression" or "Great Depression" or "inbreeding	304,628

	depression" or "orange fluorescence" or "MdPI depression" or "fruit bat*" or duck or ducks or bird or birds or turkey* or chicken* or insect* or "fruit fly" or "mito* depression" or aromatherapy or "Agent Orange" or "Orange County" or Cherry Valley or "Medlars Service" or dementia* or alzheimer*)	
S6	TI=("older adult*" or elderly)	3,000
S7	#6 OR #5 OR #4	307,186
S8	#3 NOT #7	325

Proquest Dissertations and These Global: up to October 30, 2020

S1	ti(("neurotic disorder" OR hypervigilance OR agoraphobia OR "dysthymic disorder" OR anxiety OR "common mental disorders" OR "internalizing symptoms" OR "internalising symptoms" OR "mental illness" OR "clinical depression" OR "major depression" OR "mental health"))	22,904
S2	ti((("high fiber" OR "high fibre" OR "dietary fiber" OR "dietary fibre" OR FRUIT OR fruits OR ACAI OR ACKEE OR "ACTINIDIA ARGUTA" OR "AIELE FRUIT*" OR AMLA OR (APPLE* NOT (phone* OR computer* OR smartphone* OR device*)) OR APRICOTS OR apricot OR ARONIA OR avocado* OR BABACO OR BACURI OR "BAEL FRUIT" OR BANANA* OR BERRIES OR Blueberries OR barberr* OR brambleberr* OR BREADFRUIT OR BUSH BUTTER OR "CACTUS PEAR*" OR CAJA OR "CAMU CAMU" OR clementines OR GOOSEBERRIES OR CARAMBOLAS OR "CASHEW APPLE*" OR CHERIMOYA OR CHERRIES OR "CHERRY LAUREL" OR CITRUS OR ORANGES OR CITRONS OR nectarine* OR TAMURANA OR currants OR Dragonfruit* OR GALGALS OR grapes OR GRAPEFRUIT* OR "KI MIKAN" OR KUMQUAT* OR LEMONS OR lemons OR LIMES OR lingonberr* OR ORTANIQUE OR POMELOS OR TANGELO OR TANGOR OR YUZU OR COCONA OR CUPUACU OR "CURCULIGO LATIFOLIA" OR DURIAN OR FEIJOA OR FORTUNELLA OR GUAVAS OR HAWTHORN OR JABOTICABA OR "JAK FRUITS" OR "JELLY FIGS" OR KIWANO OR KIWIFRUIT OR "kiwi fruit*" OR LANGSAT OR LITCHIS OR LONGANS OR LOQUATS OR MAMEY OR MANGOES OR MANGOSTEENS OR MARULA OR MEDLARS OR medlar OR MELON OR melons OR CANTALOUPE* OR HONEYDEW OR MUSKMELONS OR MYROBALANS OR MYRTLE OR NARANJILLA OR NONI OR OLIVES OR OMIJA OR PAPAYAS OR "PASSION FRUIT*" OR passionfruit* OR PEACHES OR peach OR PEARS OR PEPINO OR PERSIMMON* OR PHALSA OR PINEAPPLE* OR PITAYOS OR PLUMS OR plum OR POMEGRANATE* OR "PRICKLY PEAR*"	91,329

	OR prune OR prunes OR QUINCE OR quinces OR RAMBUTAN OR rhubarb OR rockmelon* OR raspberr* OR ROSEHIP* OR SAPODILLA* OR SASKATOONS OR "saskatoon berries" OR "SEA BUCKTHORN*" OR SLOES OR SOURSOP OR SPONDIAS OR STARfruit* OR strawberr* OR tangerine* OR tangelo* OR TAMARIND* OR TOMATILLO* OR TOMATO* OR WATERMELON* OR EGUSI OR bearberr* OR soapberr* OR salmonberr* OR crowberr* OR huckleberr* OR haskap OR cranberr* OR chokecherr* OR pincherr* OR cloudberr* OR dewberr* OR elderberr* OR "partride berries" OR artichoke* OR arugula OR Asparagus OR aubergine* OR "bamboo shoot*" OR basil OR bean OR beans OR beet OR beets OR beetroot* OR "bok choy" OR broadbean* OR broccoflower OR broccoli OR "brussel* sprout*" OR cabbage* OR caraway OR carrot* OR cauliflower* OR capsicum* OR celeriac OR celery* OR chickpea* OR chives OR cilantro OR collard* OR coriander OR corn OR courgette* OR cucumber* OR daikon OR edemame OR eggplant* OR endive OR endives OR fennel OR fiddlehead* OR garbanzos OR garlic OR ginger OR jimcama OR kale OR kohlrabi OR leek* OR legume* OR lentil OR lentils OR lettuce* OR okra OR onion* OR oregano OR peas OR parsley OR parsnip* OR pepper* OR potato* OR pumpkin* OR radish* OR radicchio OR rutabaga* OR salad OR salads OR salsify OR scallion* OR shallot* OR sorrel OR soybean* OR spinach OR squash OR sweetcorn OR "Swiss chard" OR taro OR tomatillo OR topinambur OR turnip* OR "water chestnut*" OR watercress OR yam OR yams OR zucchini* OR vegetable*))) OR ab((("high fiber" OR "high fibre" OR "dietary fiber" OR "dietary fibre" OR FRUIT OR fruits OR ACAI OR ACKEE OR "ACTINIDIA ARGUTA" OR "AIELE FRUIT*" OR AMLA OR (APPLE* NOT (phone* OR computer* OR smartphone* OR device*)) OR APRICOTS OR apricot OR ARONIA OR avocado* OR BABACO OR BACURI OR "BAEL FRUIT" OR BANANA* OR BERRIES OR Blueberries OR barberr* OR brambleberr* OR BREADFRUIT OR BUSH BUTTER OR "CACTUS PEAR*" OR CAJA OR "CAMU CAMU" OR clementines OR GOOSEBERRIES OR CARAMBOLAS OR "CASHEW APPLE*" OR CHERIMOYA OR CHERRIES OR "CHERRY LAUREL" OR CITRUS OR ORANGES OR CITRONS OR nectarine* OR TAMURANA OR currants OR Dragonfruit* OR GALGALS OR grapes OR GRAPEFRUIT* OR "KI MIKAN" OR KUMQUAT* OR LEMONS OR lemons OR LIMES OR lingonberr* OR ORTANIQUE OR POMELOS OR TANGELO OR TANGOR OR YUZU OR COCONA OR CUPUACU OR "CURCULIGO LATIFOLIA" OR DURIAN OR FEIJOA OR FORTUNELLA OR GUAVAS OR HAWTHORN OR JABOTICABA OR "JAK FRUITS" OR "JELLY FIGS" OR KIWANO OR KIWIFRUIT OR "kiwi fruit*" OR LANGSAT OR LITCHIS OR LONGANS OR LOQUATS OR MAMEY OR MANGOES OR	

	MANGOSTEENS OR MARULA OR MEDLARS OR medlar OR MELON OR melons OR CANTALOUPE* OR HONEYDEW OR MUSKMELONS OR MYROBALANS OR MYRTLE OR NARANJILLA OR NONI OR OLIVES OR OMIJA OR PAPAYAS OR "PASSION FRUIT*" OR passionfruit* OR PEACHES OR peach OR PEARS OR PEPINO OR PERSIMMON* OR PHALSA OR PINEAPPLE* OR PITAYOS OR PLUMS OR plum OR POMEGRANATE* OR "PRICKLY PEAR*" OR prune OR prunes OR QUINCE OR quinces OR RAMBUTAN OR rhubarb OR rockmelon* OR raspberr* OR ROSEHIP* OR SAPODILLA* OR SASKATOONS OR "saskatoon berries" OR "SEA BUCKTHORN*" OR SLOES OR SOURSOP OR SPONDIAS OR STARfruit* OR strawberr* OR tangerine* OR tangelo* OR TAMARIND* OR TOMATILLO* OR TOMATO* OR WATERMELON* OR EGUSI OR bearberr* OR soapberr* OR salmonberr* OR crowberr* OR huckleberr* OR haskap OR cranberr* OR chokecherr* OR pincherr* OR cloudberr* OR dewberr* OR elderberr* OR "partridge berries" OR artichoke* OR arugula OR Asparagus OR aubergine* OR "bamboo shoot*" OR basil OR bean OR beans OR beet OR beets OR beetroot* OR "bok choy" OR broadbean* OR broccoflower OR broccoli OR "brussel* sprout*" OR cabbage* OR caraway OR carrot* OR cauliflower* OR capsicum* OR celeriac OR celery* OR chickpea* OR chives OR cilantro OR collard* OR coriander OR corn OR courgette* OR cucumber* OR daikon OR edemame OR eggplant* OR endive OR endives OR fennel OR fiddlehead* OR garbanzos OR garlic OR ginger OR jimcama OR kale OR kohlrabi OR leek* OR legume* OR lentil OR lentils OR lettuce* OR okra OR onion* OR oregano OR peas OR parsley OR parsnip* OR pepper* OR potato* OR pumpkin* OR radish* OR radicchio OR rutabaga* OR salad OR salads OR salsify OR scallion* OR shallot* OR sorrel OR soybean* OR spinach OR squash OR sweetcorn OR "Swiss chard" OR taro OR tomatillo OR topinambur OR turnip* OR "water chestnut*" OR watercress OR yam OR yams OR zucchini* OR vegetable*)))	
S3	noft((animal* OR rat OR rats OR mouse OR mice OR rabbit* OR cat OR cats OR dog OR dogs OR pig OR pigs OR piglet* OR procine OR canine OR rodent* OR feline* OR sheep OR ewe OR lamb OR goat OR goats OR cow OR cows OR cattle OR bison* OR buffalo* bovine OR horse OR horses OR equine OR fish OR fishes OR "Afar Depression" OR "Great Depression" OR "inbreeding depression" OR "orange fluorescence" OR "MdPI depression" OR "fruit bat*" OR duck OR ducks OR bird OR birds OR turkey* OR chicken* OR insect* OR "fruit fly" OR "mito* depression" OR aromatherapy OR "Agent Orange" OR "Orange County" OR Cherry Valley OR "Medlars Service" OR dementia* OR alzheimer* OR "green space" or berry))	372,907
S4	S1 and S2	88
S5	S4 not s3	38

PROSPERO: up to October 30, 2020

#1	((("neurotic disorder" OR hypervigilance OR agoraphobia OR "dysthymic disorder" OR anxiety OR "common mental disorders" OR "internalizing symptoms" OR "internalising symptoms" OR "mental illness" OR "clinical depression" OR "major depression" OR "mental health"))):TI	1619
#2	("high fiber" OR "high fibre" OR "dietary fiber" OR "dietary fibre" OR FRUIT OR fruits OR ACAI OR ACKEE OR "ACTINIDIA ARGUTA" OR "AIELE FRUIT*" OR AMLA OR (APPLE* NOT (phone* OR computer* OR smartphone* OR device*)) OR APRICOTS OR apricot OR ARONIA OR avocado* OR BABACO OR BACURI OR "BAEL FRUIT" OR BANANA* OR BERRIES OR Blueberries OR barberr* OR brambleberr* OR BREADFRUIT OR BUSH BUTTER OR "CACTUS PEAR*" OR CAJA OR "CAMU CAMU" OR clementines OR GOOSEBERRIES OR CARAMBOLAS OR "CASHEW APPLE*" OR CHERIMOYA OR CHERRIES OR "CHERRY LAUREL" OR CITRUS OR ORANGES OR CITRONS OR nectarine* OR TAMURANA OR currants OR Dragonfruit* OR GALGALS OR grapes OR GRAPEFRUIT* OR "KI MIKAN" OR KUMQUAT* OR LEMONS OR lemons OR LIMES OR lingonberr* OR ORTANIQUE OR POMELOS OR TANGELO OR TANGOR OR YUZU OR COCONA OR CUPUACU OR "CURCULIGO LATIFOLIA" OR DURIAN OR FEIJOA OR FORTUNELLA OR GUAVAS OR HAWTHORN OR JABOTICABA OR "JAK FRUITS" OR "JELLY FIGS" OR KIWANO OR KIWIFRUIT OR "kiwi fruit*" OR LANGSAT OR LITCHIS OR LONGANS OR LOQUATS OR MAMEY OR MANGOES OR MANGOSTEENS OR MARULA OR MEDLARS OR medlar OR MELON OR melons OR CANTALOUPE* OR HONEYDEW OR MUSKMELONS OR MYROBALANS OR MYRTLE OR NARANJILLA OR NONI OR OLIVES OR OMIJA OR PAPAYAS OR "PASSION FRUIT*" OR passionfruit*):TI	65
#3	(PEACHES OR peach OR PEARS OR PEPINO OR PERSIMMON* OR PHALSA OR PINEAPPLE* OR PITAYOS OR PLUMS OR plum OR POMEGRANATE* OR "PRICKLY PEAR*" OR prune OR prunes OR QUINCE OR quinces OR RAMBUTAN OR rhubarb OR rockmelon* OR raspberr* OR ROSEHIP* OR SAPODILLA* OR SASKATOONS OR "saskatoon berries" OR "SEA BUCKTHORN*" OR SLOES OR SOURSOP OR SPONDIAS OR STARfruit* OR strawberr* OR tangerine* OR tangelo* OR TAMARIND* OR TOMATILLO* OR TOMATO* OR WATERMELON* OR EGUSI OR bearberr* OR soapberr* OR salmonberr* OR crowberr* OR huckleberr* OR haskap OR cranberr* OR chokecherr* OR pincherr*	64

	OR cloudberr* OR dewberr* OR elderberr* OR "partridge berries" OR artichoke* OR arugula OR Asparagus OR aubergine* OR "bamboo shoot*" OR basil OR bean OR beans OR beet OR beets OR beetroot* OR "bok choy" OR broadbean* OR broccoflower OR broccoli OR "brussel* sprout*" OR cabbage* OR caraway OR carrot* OR cauliflower* OR capsicum* OR celeriac OR celery* OR chickpea* OR chives OR cilantro OR collard* OR coriander OR corn OR courgette* OR cucumber* OR daikon OR edemame OR eggplant* OR endive OR endives OR fennel OR fiddlehead* OR garbanzos OR garlic OR ginger OR jimcama OR kale OR kohlrabi OR leek* OR legume* OR lentil OR lentils OR lettuce* OR okra OR onion* OR oregano OR peas OR parsley OR parsnip* OR pepper* OR potato* OR pumpkin* OR radish* OR radicchio OR rutabaga* OR salad OR salads OR salsify OR scallion* OR shallot* OR sorrel OR soybean* OR spinach OR squash OR sweetcorn OR "Swiss chard" OR taro OR tomatillo OR topinambur OR turnip* OR "water chestnut*" OR watercress OR yam OR yams OR zucchini):TI	
#4	(vegetable*):TI	33
#5	#2 OR #3 OR #4	136
#6	#1 AND #5	2

CINAHL (EBSCO) up to October 30, 2020

S1	(MH "Fruit+") OR (MH "Berries") OR (MH "Cherries") OR (MH "Citrus") or (MH "Vegetables+")	34,631
S2	TI("high fiber" OR "high fibre" OR "dietary fiber" OR "dietary fibre" OR FRUIT OR fruits OR ACAI OR ACKEE OR "ACTINIDIA ARGUTA" OR "AIELE FRUIT*" OR AMLA OR (APPLE* NOT (phone* OR computer* OR smartphone* OR device*)) OR APRICOTS OR apricot OR ARONIA OR avocado* OR BABACO OR BACURI OR "BAEL FRUIT" OR BANANA* OR BERRIES OR Blueberries OR barberr* OR brambleberr* OR BREADFRUIT OR BUSH BUTTER OR "CACTUS PEAR*" OR CAJA OR "CAMU CAMU" OR clementines OR GOOSEBERRIES OR CARAMBOLAS OR "CASHEW APPLE*" OR CHERIMOYA OR CHERRIES OR "CHERRY LAUREL" OR CITRUS OR ORANGES OR CITRONS OR nectarine* OR TAMURANA OR currants OR Dragonfruit* OR GALGALS OR grapes OR GRAPEFRUIT* OR "KI MIKAN" OR KUMQUAT* OR LEMONS OR lemons OR LIMES OR lingonberr* OR ORTANIQUE OR POMELOS OR TANGELO OR TANGOR OR YUZU OR COCONA OR CUPUACU OR "CURCULIGO LATIFOLIA" OR DURIAN OR FEIJOA OR FORTUNELLA OR GUAVAS OR HAWTHORN OR JABOTICABA OR "JAK FRUITS" OR "JELLY FIGS" OR KIWANO OR KIWIFRUIT OR "kiwi fruit*" OR LANGSAT OR LITCHIS OR LONGANS OR LOQUATS OR	19,574

	MAMEY OR MANGOES OR MANGOSTEENS OR MARULA OR MEDLARS OR medlar OR MELON OR melons OR CANTALOUPE* OR HONEYDEW OR MUSKMELONS OR MYROBALANS OR MYRTLE OR NARANJILLA OR NONI OR OLIVES OR OMIJA OR PAPAYAS OR "PASSION FRUIT*" OR passionfruit* OR PEACHES OR peach OR PEARS OR PEPINO OR PERSIMMON* OR PHALSA OR PINEAPPLE* OR PITAYOS OR PLUMS OR plum OR POMEGRANATE* OR "PRICKLY PEAR*" OR prune OR prunes OR QUINCE OR quinces OR RAMBUTAN OR rhubarb OR rockmelon* OR raspberr* OR ROSEHIP* OR SAPODILLA* OR SASKATOONS OR "saskatoon berries" OR "SEA BUCKTHORN*" OR SLOES OR SOURSOP OR SPONDIAS OR STARfruit* OR strawberr* OR tangerine* OR tangelo* OR TAMARIND* OR TOMATILLO* OR TOMATO* OR WATERMELON* OR EGUSI OR bearberr* OR soapberr* OR salmonberr* OR crowberr* OR huckleberr* OR haskap OR cranberr* OR chokecherr* OR pincherr* OR cloudberr* OR dewberr* OR elderberr* OR "partridge berries" OR artichoke* OR arugula OR Asparagus OR aubergine* OR "bamboo shoot*" OR basil OR bean OR beans OR beet OR beets OR beetroot* OR "bok choy" OR broadbean* OR broccoflower OR broccoli OR "brussel* sprout*" OR cabbage* OR caraway OR carrot* OR cauliflower* OR capsicum* OR celeriac OR celery* OR chickpea* OR chives OR cilantro OR collard* OR coriander OR corn OR courgette* OR cucumber* OR daikon OR edemame OR eggplant* OR endive OR endives OR fennel OR fiddlehead* OR garbanzos OR garlic OR ginger OR jimcama OR kale OR kohlrabi OR leek* OR legume* OR lentil OR lentils OR lettuce* OR okra OR onion* OR oregano OR peas OR parsley OR parsnip* OR pepper* OR potato* OR pumpkin* OR radish* OR radicchio OR rutabaga* OR salad OR salads OR salsify OR scallion* OR shallot* OR sorrel OR soybean* OR spinach OR squash OR sweetcorn OR "Swiss chard" OR taro OR tomatillo OR topinambur OR turnip* OR "water chestnut*" OR watercress OR yam OR yams OR zucchini* OR vegetable*)))	
S3	AB("high fiber" OR "high fibre" OR "dietary fiber" OR "dietary fibre" OR FRUIT OR fruits OR ACAI OR ACKEE OR "ACTINIDIA ARGUTA" OR "AIELE FRUIT*" OR AMLA OR (APPLE* NOT (phone* OR computer* OR smartphone* OR device*)) OR APRICOTS OR apricot OR ARONIA OR avocado* OR BABACO OR BACURI OR "BAEL FRUIT" OR BANANA* OR BERRIES OR Blueberries OR barberr* OR brambleberr* OR BREADFRUIT OR BUSH BUTTER OR "CACTUS PEAR*" OR CAJA OR "CAMU CAMU" OR clementines OR GOOSEBERRIES OR CARAMBOLAS OR "CASHEW APPLE*" OR CHERIMOYA OR CHERRIES OR "CHERRY LAUREL" OR CITRUS OR ORANGES OR CITRONS OR nectarine* OR TAMURANA OR currants OR Dragonfruit* OR	35,392

	GALGALS OR grapes OR GRAPEFRUIT* OR "KI MIKAN" OR KUMQUAT* OR LEMONS OR lemons OR LIMES OR lingonberr* OR ORTANIQUE OR POMELOS OR TANGELO OR TANGOR OR YUZU OR COCONA OR CUPUACU OR "CURCULIGO LATIFOLIA" OR DURIAN OR FEIJOA OR FORTUNELLA OR GUAVAS OR HAWTHORN OR JABOTICABA OR "JAK FRUITS" OR "JELLY FIGS" OR KIWANO OR KIWIFRUIT OR "kiwi fruit*" OR LANGSAT OR LITCHIS OR LONGANS OR LOQUATS OR MAMEY OR MANGOES OR MANGOSTEENS OR MARULA OR MEDLARS OR medlar OR MELON OR melons OR CANTALOUPE* OR HONEYDEW OR MUSKMELONS OR MYROBALANS OR MYRTLE OR NARANJILLA OR NONI OR OLIVES OR OMIJA OR PAPAYAS OR "PASSION FRUIT*" OR passionfruit* OR PEACHES OR peach OR PEARS OR PEPINO OR PERSIMMON* OR PHALSA OR PINEAPPLE* OR PITAYOS OR PLUMS OR plum OR POMEGRANATE* OR "PRICKLY PEAR*" OR prune OR prunes OR QUINCE OR quinces OR RAMBUTAN OR rhubarb OR rockmelon* OR raspberr* OR ROSEHIP* OR SAPODILLA* OR SASKATOONS OR "saskatoon berries" OR "SEA BUCKTHORN*" OR SLOES OR SOURSOP OR SPONDIAS OR STARfruit* OR strawberr* OR tangerine* OR tangelo* OR TAMARIND* OR TOMATILLO* OR TOMATO* OR WATERMELON* OR EGUSI OR bearberr* OR soapberr* OR salmonberr* OR crowberr* OR huckleberr* OR haskap OR cranberr* OR chokecherr* OR pincherr* OR cloudberr* OR dewberr* OR elderberr* OR "partrigde berries" OR artichoke* OR arugula OR Asparagus OR aubergine* OR "bamboo shoot*" OR basil OR bean OR beans OR beet OR beets OR beetroot* OR "bok choy" OR broadbean* OR broccoflower OR broccoli OR "brussel* sprout*" OR cabbage* OR caraway OR carrot* OR cauliflower* OR capsicum* OR celeriac OR celery* OR chickpea* OR chives OR cilantro OR collard* OR coriander OR corn OR courgette* OR cucumber* OR daikon OR edemame OR eggplant* OR endive OR endives OR fennel OR fiddlehead* OR garbanzos OR garlic OR ginger OR jimcama OR kale OR kohlrabi OR leek* OR legume* OR lentil OR lentils OR lettuce* OR okra OR onion* OR oregano OR peas OR parsley OR parsnip* OR pepper* OR potato* OR pumpkin* OR radish* OR radicchio OR rutabaga* OR salad OR salads OR salsify OR scallion* OR shallot* OR sorrel OR soybean* OR spinach OR squash OR sweetcorn OR "Swiss chard" OR taro OR tomatillo OR topinambur OR turnip* OR "water chestnut*" OR watercress OR yam OR yams OR zucchini* OR vegetable*)))	
S4	S1 OR S2 OR S3	63,270
S5	(MH "Anxiety")	37,128
S6	(MH "Anxiety Disorders") OR (MH "Behavioral and Mental Disorders") OR (MH "Neurotic Disorders") OR (MH "Generalized	10,854

	Anxiety Disorder")	
S7	(MH "Depression") OR (MH "Dysthymic Disorder") OR (MH "Seasonal Affective Disorder")	95,144
S8	TI ("mental health" or "mental illness" or anxiety or depression or depressive or "common mental disorders" or "neurotic disorder*" or "dysthymic disorder" or "seasonal affective disorder*" or "internalizing symptoms" or "internalising symptoms") OR AB ("mental health" or "mental illness" or anxiety or depression or depressive or "common mental disorders" or "neurotic disorder*" or "dysthymic disorder" or "seasonal affective disorder*" or "internalizing symptoms" or "internalising symptoms")	231,948
S9	S5 OR S6 OR S7 OR S8	265,301
S10	S4 AND S9	1,157
S11	S4 AND S9	1,157
S12	S4 AND S9	1,157
S13	(s10 not s11) or s12	807
S14	(MH "Animal Diseases+") OR (MH "Animal Studies") OR (MH "Animals, Laboratory")	110,389
S15	TI ("nursing home*" or elderly or geriatric* or woman or women or man or men or "graduate student*" or adult* or "senior citizen*" or "middle aged")	336,132
S16	(animal* OR rat OR rats OR mouse OR mice OR rabbit* OR cat OR cats OR dog OR dogs OR pig OR pigs OR piglet* OR procine OR canine OR rodent* OR feline* OR sheep OR ewe OR lamb OR goat OR goats OR cow OR cows OR cattle OR bison* OR buffalo* bovine OR horse OR horses OR equine OR fish OR fishes OR "Afar Depression" OR "Great Depression" OR "inbreeding depression" OR "orange fluorescence" OR "MdPI depression" OR "fruit bat*" OR duck OR ducks OR bird OR birds OR turkey* OR chicken* OR insect* OR "fruit fly" OR "mito* depression" OR aromatherapy OR "Agent Orange" OR "Orange County" OR Cherry Valley OR "Medlars Service" OR dementia* OR alzheimer* OR "green space" or berry)	361,071
S17	S14 OR S15 OR S16	681,904
S18	s13 not s17	520
S19	adult* AND (“middle school*” or pubescen* or juvenile* or teen* or youth* or “high school*” or adolesc*or prepubesc* or “pre-pubesc*”)	25,388
S20	adult*	1,203,833
S21	adult*	317,427
S22	S19 OR S21	323,611
S23	s20 not s22	880,222
S24	s18 not s23	495

CAB Abstracts (Web of Knowledge): up to October 30, 2020

#1	TOPIC: ("neurotic disorder" or hypervigilance or agoraphobia or "dysthymic disorder" or anxiety or "common mental disorders" or cmd or "internalizing symptoms" or "internalising symptoms" or "mental illness" or "clinical depression" or "major depression" or "mental health")	30,620
#2	DESCRIPTORS: (depression or anxiety)	18,200
#3	#1 or #2	32,671
#4	DESCRIPTORS: (vegetables OR mushrooms OR bulbous vegetables OR fruit vegetables OR leafy vegetables OR root vegetables OR stem vegetables)	218,070
#5	DESCRIPTORS: (fruit crops OR cucurbit fruits OR melons OR watermelons OR grapes OR subtropical fruits OR subtropical small fruits OR passion fruits OR tamarillos OR subtropical tree fruits OR avocados OR carobs OR citrus fruits OR calamondins OR citrangequats OR citranges OR citremons OR citrons OR citrumelos OR clementines OR grapefruits OR kumquats OR lemons OR limes OR mandarins OR natsudaidais OR oranges OR ortaniques OR pummelos OR rough lemons OR satsumas OR sour oranges OR tangelos OR tangors OR dates OR feijoas OR longans OR loquats OR olives OR persimmons OR pomegranates OR temperate fruits OR temperate small fruits OR bilberries OR black currants OR blackberries OR blueberries OR boysenberries OR cranberries OR gooseberries OR kiwifruits OR loganberries OR raspberries OR red currants OR strawberries OR tayberries OR white currants OR temperate tree fruits OR tropical fruits OR tropical small fruits OR bananas OR pineapples OR tropical tree fruits OR small fruits OR subtropical small fruits OR temperate small fruits OR tropical small fruits OR tree fruits OR subtropical tree fruits OR temperate tree fruits OR tropical tree fruits)	406,040
#6	567,984 TITLE: ((("high fiber" or "high fibre" or "dietary fiber" or "dietary fibre" or FRUIT or fruits or ACAI or ACKEE or "ACTINIDIA ARGUTA" or "AIELE FRUIT*" or AMLA or (APPLE* not (phone* or computer* or smartphone* or device*)) or APRICOTS or apricot or ARONIA or avocado* or BABACO or BACURI or "BAEL FRUIT" or BANANA* or BERRIES or Blueberries or barberr* or brambleberr* or BREADFRUIT or BUSH BUTTER or "CACTUS PEAR*" or CAJA or "CAMU CAMU" or clementines or GOOSEBERRIES or CARAMBOLAS or "CASHEW APPLE*" or CHERIMOYA or CHERRIES or "CHERRY LAUREL" or CITRUS or ORANGES or CITRONS or nectarine* or TAMURANA or currants or Dragonfruit* or GALGALS or grapes or GRAPEFRUIT* or "KI MIKAN" or KUMQUAT* or LEMONS or lemons or LIMES or lingonberr* or ORTANIQUE or POMELOS or TANGELO or	582,824

	TANGOR or YUZU or COCONA or CUPUACU or "CURCULIGO LATIFOLIA" or DURIAN or FEIJOA or FORTUNELLA or GUAVAS or HAWTHORN or JABOTICABA or "JAK FRUITS" or "JELLY FIGS" or KIWANO or KIWIFRUIT or "kiwi fruit*" or LANGSAT or LITCHIS or LONGANS or LOQUATS or MAMEY or MANGOES or MANGOSTEENS or MARULA or MEDLARS or medlar or MELON or melons or CANTALOUPE* or HONEYDEW or MUSKMELONS or MYROBALANS or MYRTLE or NARANJILLA or NONI or OLIVES or OMIJA or PAPAYAS or "PASSION FRUIT*" or passionfruit* or PEACHES or peach or PEARS or PEPINO or PERSIMMON* or PHALSA or PINEAPPLE* or PITAYOS or PLUMS or plum or POMEGRANATE* or "PRICKLY PEAR*" or prune or prunes or QUINCE or quinces or RAMBUTAN or rhubarb or rockmelon* or raspberr* or ROSEHIP* or SAPODILLA* or SASKATOONS or "saskatoon berr*" or "SEA BUCKTHORN*" or SLOES or SOURSOP or SPONDIAS or STARfruit* or strawberr* or tangerine* or tangelo* or TAMARIND* or TOMATILLO* or TOMATO* or WATERMELON* or EGUSI or bearberr* or soapberr* or salmonberr* or crowberr* or huckleberr* or haskap or cranberr* or chokecherr* or pincherr* or cloudberr* or dewberr* or elderberr* or "partridge berr*")) OR TOPIC: ((Artichoke* or arugula or Asparagus or aubergine* or "bamboo shoot*" or basil or bean or beans or beet or beets or beetroot* or "bok choy" or broadbean* or broccoflower or broccoli or "brussel* sprout*" or cabbage* or caraway or carrot* or cauliflower* or capsicum* or celeriac or celery* or chickpea* or chives or cilantro or collard* or coriander or corn or courgette* or cucumber* or daikon or edemame or eggplant* or endive or endives or fennel or fiddlehead* or garbanzos or garlic or ginger or greens or jimcama or kale or kohlrabi or leek* or legume* or lentil or lentils or lettuce* or okra or onion* or oregano or peas or parsley or parsnip* or pepper* or potato* or pumpkin* or radish* or radicchio or rutabaga* or salad or salads or salsify or scallion* or shallot* or sorrel or soybean* or spinach or squash or sweetcorn or "Swiss chard" or taro or tomatillo or topinambur or turnip* or "water chestnut*" or watercress or yam or yams or zucchini* or vegetable*)) OR DESCRIPTORS: (VEGETABLES OR DRIED PEAS OR DRIED VEGETABLES OR VEGETABLES SPECIFIC OR ALLIUM OR AMARANTH LEAVES OR ANU OR ARRACACHA OR ARROWHEAD OR ARTICHOKES OR ASPARAGUS OR AUBERGINES OR AVOCADOS OR BAMBOO OR BAOBAB OR BEETS OR BITTER LEAF OR BLACK SALSIFY OR BORAGE OR BOXTHORN OR BRASSICA OR BROCCOLI OR BRUSSELS SPROUTS OR BURDOCK OR BUTTERBUR OR CABBAGES OR CANNA OR CAPSICUMS OR CARDOONS OR CARROTS OR CASSAVA OR CAULIFLOWERS OR CELERIAC OR CELERY OR CEYLON	

	SPINACH OR CHAYOTE OR CHICORY (VEGETABLES) OR CHINESE CABBAGES OR CHINESE CHIVES OR CHINESE WATER CHESTNUTS OR CHUFA NUTS OR COCOYAMS OR CORCHORUS OLITORIUS OR COURGETTES OR CRESS OR CRUCIFERAE OR CUCUMBERS OR CUCURBITACEAE OR CURCUMA OR DANDELIONS OR EDIBLE FLOWERS OR ELEPHANT YAMS OR ENDIVES OR ERUCA SATIVA OR EWEDU OR EXOTIC VEGETABLES OR FENNEL OR FENUGREEK OR FUNGI EDIBLE OR GHERKINS OR GLOBE ARTICHOKES OR GODULBAEGI OR GOURDS OR GREEN VEGETABLES OR HOUTTUYNIA CORDATA OR INDIAN SPINACH OR JERUSALEM ARTICHOKES OR KALE OR KOHLRABI OR KOMATSUNA OR KUDZU OR LEAFY VEGETABLES OR LEEKS OR LEGUMES OR LETTUCES OR LILY BULBS OR LOTUS ROOTS OR MACA OR MARROWS OR MUSTARD GREENS OR NETTLES OR OCA OR OKRA OR ONIONS OR PALM HEARTS OR PARSNIPS OR PERILLA OR POTATOES OR PUMPKINS OR PURSLANE OR RADISHES OR RAKKYO OR RHUBARB OR ROCKET OR ROOT CROPS OR ROOT VEGETABLES OR SALAD VEGETABLES OR SALSIFY OR SCALLION OR SEA KALE OR SESBANIA OR SHALLOTS OR SOLANUM OR SPINACH OR SPROUTS OR SQUASHES OR SWEDES OR SWEET POTATOES OR SWEETCORN OR SWISS CHARD OR TUBERS OR TURNIPS OR ULLUCO OR VINE LEAVES OR WATER CHESTNUTS OR WATER DROPWORT OR WATER SPINACH OR WATERCRESS OR WELSH ONIONS OR WILD CABBAGE OR WILD VEGETABLES OR YACON OR YAMS OR ZEDOARY)) Indexes=CAB Abstracts Timespan=All years	
#7	#6 OR #5 OR #4	894,183
#8	#7 AND #3	978
#9	DESCRIPTORS: (laboratory animals)	132,386
#10	DESCRIPTORS: (animal models)	246,288
#11	TOPIC: (rat OR rats OR mouse OR mice OR rabbit* OR cat OR cats OR dog OR dogs OR pig OR pigs OR piglet* OR procine OR canine OR rodent* OR feline* OR sheep OR ewe OR lamb OR goat OR goats OR cow OR cows OR cattle OR bison* OR buffalo* bovine OR horse OR horses OR equine OR fish OR fishes OR "Afar Depression" OR "Great Depression" OR "inbreeding depression" OR "orange fluorescence" OR "MdPI depression" OR "fruit bat*" OR duck OR ducks OR bird OR birds OR turkey* OR chicken* OR insect* OR "fruit fly" OR "mito* depression" OR aromatherapy OR "Agent Orange" OR "Orange County" OR Cherry Valley OR "Medlars Service" OR dementia* OR alzheimer* OR "green space")	3,903,342
#12	#11 OR #10 OR #9	3,922,324
#13	#8 not #12	393

Cochrane Library (Wiley): April 1996 - October 30 2020

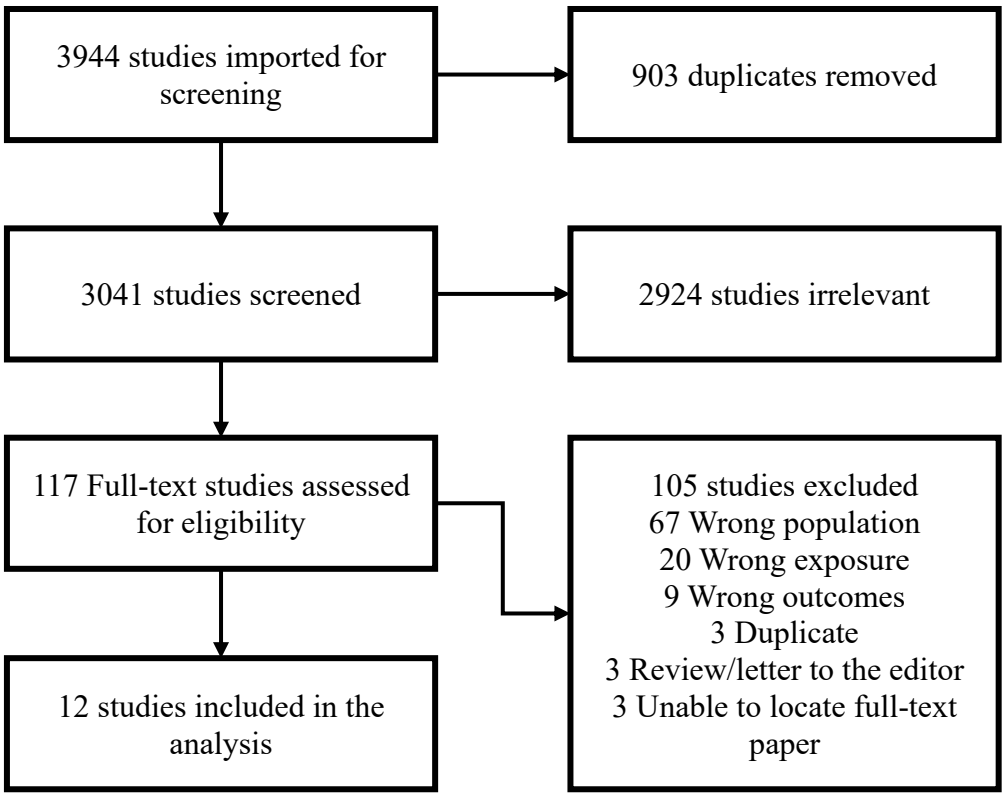
#1	MeSH descriptor: [Fruit] explode all trees	2535
#2	MeSH descriptor: [Vegetables] explode all trees	1815
#3	("high fiber" or "high fibre" or "dietary fiber" or "dietary fibre" or FRUIT or fruits or ACAI or ACKEE or "ACTINIDIA ARGUTA" or "AIELE FRUIT*" or AMLA or (APPLE* not (phone* or computer* or smartphone* or device*)) or APRICOTS or apricot or ARONIA or avocado* or BABACO or BACURI or "BAEL FRUIT" or BANANA* or BERRIES or Blueberries or barberr* or brambleberr* or BREADFRUIT or BUSH BUTTER or "CACTUS PEAR*" or CAJA or "CAMU CAMU" or clementines or GOOSEBERRIES or CARAMBOLAS or "CASHEW APPLE*" or CHERIMOYA or CHERRIES or "CHERRY LAUREL" or CITRUS or ORANGES or CITRONS or nectarine* or TAMURANA or currants or Dragonfruit* or GALGALS or grapes or GRAPEFRUIT* or "KI MIKAN" or KUMQUAT* or LEMONS or lemons or LIMES or lingonberr* or ORTANIQUE or POMELOS or TANGELO or TANGOR or YUZU or COCONA or CUPUACU or "CURCULIGO LATIFOLIA" or DURIAN or FEIJOA or FORTUNELLA or GUAVAS or HAWTHORN or JABOTICABA or "JAK FRUITS" or "JELLY FIGS" or KIWANO or KIWIFRUIT or "kiwi fruit*" or LANGSAT or LITCHIS or LONGANS or LOQUATS or MAMEY or MANGOES or MANGOSTEENS or MARULA or MEDLARS or medlar or MELON or melons or CANTALOUPE* or HONEYDEW or MUSKMELONS or MYROBALANS or MYRTLE or NARANJILLA or NONI or OLIVES or OMIJA or PAPAYAS or "PASSION FRUIT*" or passionfruit* or PEACHES or peach or PEARS or PEPINO or PERSIMMON* or PHALSA or PINEAPPLE* or PITAYOS or PLUMS or plum or POMEGRANATE* or "PRICKLY PEAR*" or prune or prunes or QUINCE or quinces or RAMBUTAN or rhubarb or rockmelon* or raspberr* or ROSEHIP* or SAPODILLA* or SASKATOONS or "saskatoon berr*" or "SEA BUCKTHORN*" or SLOES or SOURSOP or SPONDIAS or STARfruit* or strawberr* or tangerine* or tangelo* or TAMARIND* or TOMATILLO* or TOMATO* or WATERMELON* or EGUSI or bearberr* or soapberr* or salmonberr* or crowberr* or huckleberr* or haskap or cranberr* or chokecherr* or pincherr* or cloudberr* or dewberr* or elderberr* or "partridge berr*" OR Artichoke* or arugula or Asparagus or aubergine* or "bamboo shoot*" or basil or bean or beans or beet or beets or beetroot* or "bok choy" or broadbean* or broccoflower or broccoli or "brussel* sprout*" or cabbage* or caraway or carrot* or cauliflower* or capsicum* or celeriac or celery* or chickpea* or chives or cilantro or collard* or coriander or corn or courgette* or cucumber* or daikon or edemame or eggplant* or endive or endives	15146

	or fennel or fiddlehead* or garbanzos or garlic or ginger or greens or jimcama or kale or kohlrabi or leek* or legume* or lentil or lentils or lettuce* or okra or onion* or oregano or peas or parsley or parsnip* or pepper* or potato* or pumpkin* or radish* or radicchio or rutabaga* or salad or salads or salsify or scallion* or shallot* or sorrel or soybean* or spinach or squash or sweetcorn or "Swiss chard" or taro or tomatillo or topinambur or turnip* or "water chestnut*" or watercress or yam or yams or zucchini* or vegetable*):ti,kw	
#4	#1 or #2 or #3	15923
#5	MeSH descriptor: [Anxiety] explode all trees	7510
#6	MeSH descriptor: [Anxiety Disorders] this term only	3334
#7	MeSH descriptor: [Depression] this term only	10762
#8	MeSH descriptor: [Depressive Disorder, Major] explode all trees	4393
#9	hypervigilance or agoraphobia or "dysthymic disorder" or anxiety or "common mental disorders" o "internalizing symptoms" or "internalising symptoms" or "mental illness" or "clinical depression" or "major depression" or "mental health":ti,ab,kw	71098
#10	#5 or #6 or #7 or #8 or #9	78087
#11	#4 and #10	296
#12	(rat OR rats OR mouse OR mice OR rabbit* OR cat OR cats OR dog OR dogs OR pig OR pigs OR piglet* OR procine OR canine OR rodent* OR feline* OR sheep OR ewe OR lamb OR goat OR goats OR cow OR cows OR cattle OR bison* OR buffalo* bovine OR horse OR horses OR equine OR fish OR fishes OR "Afar Depression" OR "Great Depression" OR "inbreeding depression" OR "orange fluorescence" OR "MdPI depression" OR "fruit bat*" OR duck OR ducks OR bird OR birds OR turkey* OR chicken* OR insect* OR "fruit fly" OR "mito* depression" OR aromatherapy OR "Agent Orange" OR "Orange County" OR Cherry Valley OR "Medlars Service" OR dementia* OR alzheimer* OR "green space" or animal*)	98475
#13	#11 not #12	202
#14	adult* or woman or man or elderly or "senior citizen*" or "nursing home*" or women or men or toddler* or preschooler*	747160
#15	#13 not #14	65

Appendices

Appendix B

PRISMA chart



Appendix C

Results of the studies (n=12) included in the systematic review.

	Statistical method	Subgroup analysis	Comparator	Effect measure	Effect size (95% CI)	Covariates adjusted for
Depression						
Fruit						
Arat 2017[96]	binomial logistic regression	Botswana	high (≥1 time/ day) vs. low (6 times or less during the past 30 days)	OR	1.01 (0.98; 1.04)	age, gender, bullying, close friends, parental control, hunger (proxy for social status)
		Kenya			1.08 (1.07; 1.09)	
		Seychelles			1.47 (1.27; 1.71)	
		Uganda			1.03 (1.01; 1.04)	
		Tanzania			1.33 (1.29; 1.38)	
		Zambia			1.17 (1.15; 1.2)	
Arat 2015[97]	simple logistic regression	Asian American	high (≥1 time/ day) vs. low (6 times or less during the past 7 days)	OR	1.29 (0.75; 2.21)	stratified by ethnicity; no other covariates controlled for in data analysis
		African American			1.14 (0.96; 1.34)	
		Caucasian			1.1 (0.9; 1.33)	
Hoare et al. 2019[98]	multiple logistic regression	N/A	consumers (i.e., consumed F/V according to 24hr recall) vs. non-consumers	OR	1.10 (0.9; 1.33)	unadjusted
					1.08 (0.9; 1.30)	age, sex
					1.07 (0.88; 1.30)	age, sex, school socioeconomic level
					1.07 (0.89; 1.28)	age, sex, school socioeconomic level, weight status
Hoare et al. 2018[100]	multiple logistic regression	females	1 time/week vs. none	OR	0.59 (0.43; 0.81)	unadjusted
			≥2 times/week vs. none		0.54 (0.40; 0.73)	
		males	1 time/week vs. none		0.48 (0.33; 0.70)	
			≥2 times/week vs. none		0.50 (0.35; 0.71)	
		females	1 time/week vs. none		0.68 (0.49; 0.95)	stratified by gender; adjusted for age, household income, ethnicity, physical activity, BMI in data analysis
			≥2 times/week vs. none		0.62 (0.45; 0.85)	
		males	1 time/week vs. none		0.53 (0.36; 0.77)	
			≥2 times/week vs. none		0.55 (0.38; 0.8)	
Hong and Peltzer 2018[101]	multivariate logistic regression	N/A	"1-2 times/week" vs. "I did not eat"	OR	0.88 (0.83; 0.94)	age, sex, socioeconomic status, school level, school types, BMI, physical activity, and substance use
			"3-4 times/week" vs. "I did not eat"		0.83 (0.77; 0.88)	
			"5-6 times/week" vs. "I did not eat"		0.83 (0.77; 0.9)	

			"once/day" vs. "I did not eat"		0.86 (0.79; 0.92)	
			"twice/day" vs. "I did not eat"		0.86 (0.78; 0.94)	
			"≥3 times/day" vs. "I did not eat"		1.05 (0.95; 1.17)	
Kim et al. 2015[106]	multivariable logistic regression	N/A	7.2-22.9 servings/week vs. 7.2 or lower	OR	0.56 (0.34; 0.94)	energy intake, menstrual regularity
			>22.9 servings/week vs. 7.2 or lower		0.63 (0.37; 1.06)	
Ming-wei Liu et al.[102]	multivariable logistic regression	Saint Lucia	<2 times/day vs. none	OR	0.92 (0.49; 1.75)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
			≥2 times/day vs. none		0.91 (0.43; 1.91)	
		Egypt	<2 times/day vs. none		0.57 (0.31; 1.02)	Age, sex, physical activity, sedentary behaviour, being bullied
			≥2 times/day vs. none		0.57 (0.31; 1.03)	
		Saint Vincent and Grenadines	<2 times/day vs. none		1.28 (0.65; 2.52)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
			≥2 times/day vs. none		1.29 (0.67; 2.50)	
		Djibouti	<2 times/day vs. none		0.98 (0.64; 1.55)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status
			≥2 times/day vs. none		0.87 (0.53; 1.45)	
		Morocco	<2 times/day vs. none		1.01 (0.46; 2.20)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
			≥2 times/day vs. none		0.75 (0.36; 1.58)	
		Myanmar	<2 times/day vs. none		1.08 (0.66; 1.77)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
			≥2 times/day vs. none		1.12 (0.62; 2.04)	
		Zambia	<2 times/day vs. none		1.52 (0.92; 2.52)	Age, sex, physical activity, sedentary behaviour, being bullied, alcohol intake
			≥2 times/day vs. none		1.26 (0.79; 2.00)	
		United Republic of Tanzania	<2 times/day vs. none		0.74 (0.51; 1.06)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
			≥2 times/day vs. none		0.67 (0.51; 0.87)	
		Venezuela	<2 times/day vs. none		0.81 (0.58; 1.12)	Age, sex, physical activity, sedentary behaviour, being bullied, alcohol intake
			≥2 times/day vs. none		0.89 (0.65; 1.21)	
		Grenada	<2 times/day vs. none		0.82 (0.42; 1.60)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
			≥2 times/day vs. none		0.59 (0.33; 1.07)	
		Lebanon	<2 times/day vs. none		0.81 (0.51; 1.27)	Age, sex, being bullied, alcohol intake
			≥2 times/day vs. none		0.82 (0.52; 1.30)	
		China	<2 times/day vs. none		0.63 (0.46; 0.86)	Age, sex, physical activity, sedentary

			≥2 times/day vs. none		0.62 (0.46; 0.83)	behaviour, being bullied, smoking status, alcohol intake
		Indonesia	<2 times/day vs. none		0.61 (0.36; 1.005)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
			≥2 times/day vs. none		0.57 (0.35; 0.92)	
		Thailand	<2 times/day vs. none		0.54 (0.31; 0.97)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
			≥2 times/day vs. none		0.56 (0.37; 0.83)	
		Uganda	<2 times/day vs. none		0.98 (0.80; 1.20)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
			≥2 times/day vs. none		0.93 (0.72; 1.21)	
		Tunisia	<2 times/day vs. none		0.67 (0.41; 1.07)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status
			≥2 times/day vs. none		0.71 (0.43; 1.20)	
		Botswana	<2 times/day vs. none		0.87 (0.57; 1.32)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
			≥2 times/day vs. none		0.70 (0.47; 1.04)	
		Sri Lanka	<2 times/day vs. none		0.77 (0.55; 1.07)	Age, sex, physical activity, sedentary behaviour, being bullied
			≥2 times/day vs. none		0.69 (0.46; 1.02)	
		India	<2 times/day vs. none		0.69 (0.53; 0.90)	Age, sex, physical activity, sedentary behaviour, smoking status
			≥2 times/day vs. none		0.67 (0.51; 0.89)	
		Seychelles	<2 times/day vs. none		0.74 (0.62; 0.87)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
			≥2 times/day vs. none		0.61 (0.52; 0.71)	
		Guyana	<2 times/day vs. none		0.81 (0.46; 1.42)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
			≥2 times/day vs. none		0.64 (0.31; 1.33)	
		Ecuador	<2 times/day vs. none		0.76 (0.56; 1.03)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
			≥2 times/day vs. none		0.71 (0.53; 0.94)	
		Jordan	<2 times/day vs. none		0.54 (0.33; 0.88)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status
			≥2 times/day vs. none		0.51 (0.29; 0.91)	
		Argentina	<2 times/day vs. none		0.83 (0.51; 1.34)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
			≥2 times/day vs. none		1.12 (0.75; 1.69)	
		Kenya	<2 times/day vs. none		0.79 (0.52; 1.22)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
			≥2 times/day vs. none		0.90 (0.61; 1.35)	
Park et al. 2018[103]	multiple logistic	N/A	high (once or more every day) vs. low-frequency	OR	1.03 (0.99; 1.08)	sex, school grade, residential area, socioeconomic status, and other dietary

	regression		consumption group (less than once per day)			behaviours (skipping breakfast, milk 2 or more times/day, fast food 3 times or more per week, soft drinks 3 times or more per week, vegetables (3 times or more per day))
Vegetables						
Arat 2017[96]	binomial logistic regression	Botswana	high (≥1 time/ day) vs. low (6 times or less during the past 7 days)	OR	1.06 (1.02; 1.09)	age, gender, bullying, close friends, parental control, hunger (proxy for social status)
		Kenya			1.11 (1.1; 1.12)	
		Seychelles			1.14 (0.97; 1.33)	
		Uganda			1.04 (1.03; 1.06)	
		Tanzania			1.14 (1.1; 1.19)	
		Zambia			1.17 (1.14; 1.19)	
Arat 2015[97]	simple logistic regression	Asian American	high (≥1 time/ day) vs. low (6 times or less during the past 7 days)	OR	1.09 (0.68; 1.74)	stratified by ethnicity; no other covariates controlled for in data analysis
		African American			0.9 (0.78; 1.04)	
		Caucasian			0.98 (0.84; 1.14)	
Hoare et al. 2019[98]	multiple logistic regression	N/A	consumers (i.e., consumed F/V according to 24hr recall) vs. non-consumers	OR	1.04 (0.87; 1.24)	unadjusted
					1.00 (0.83; 1.21)	age, sex
					0.99 (0.79; 1.25)	age, sex, school socioeconomic level
					1 (0.84; 1.2)	age, sex, school socioeconomic level, weight status
Hoare et al. 2018[100]	multiple logistic regression	females	1 time/week vs. none	OR	0.65 (0.49; 0.85)	unadjusted
			≥2 times/week vs. none		0.54 (0.39; 0.73)	
		males	1 time/week vs. none		0.79 (0.56; 1.11)	
			≥2 times/week vs. none		0.79 (0.54; 1.16)	
		females	1 time/week vs. none		0.69 (0.52; 0.93)	stratified by gender; adjusted for age, household income, ethnicity, physical activity, BMI in data analysis
			≥2 times/week vs. none		0.64 (0.46; 0.88)	
		males	1 time/week vs. none		0.8 (0.56; 1.13)	
			≥2 times/week vs. none		0.87 (0.59; 1.28)	
Hong and Peltzer 2018[101]	multivariate logistic regression	N/A	"1-2 times/week" vs. "I did not eat"	OR	0.9 (0.82; 1)	age, sex, socioeconomic status, school level, school types, Body Mass Index, physical activity, and substance use
			"3-4 times/week" vs. "I did not eat"		0.79 (0.72; 0.87)	
			"5-6 times/week" vs. "I did not eat"		0.8 (0.72; 0.88)	
			"once/day" vs. "I did not eat"		0.84 (0.76; 0.93)	
			"twice/day" vs. "I did not eat"		0.78 (0.7; 0.86)	
			"≥3 times/day" vs. "I did not		0.83 (0.75; 0.92)	

			eat"			
Kim et al. 2015[106]	multivariable logistic regression	N/A	7.2-22.9 servings/week compared to 7.2 or lower	OR	1 (0.62; 1.61)	energy intake, menstrual regularity
			>22.9 servings/week compared to 7.2 or lower		0.61 (0.35; 1.04)	
Ming-wei Liu et al.[102]	multivariable logistic regression	Saint Lucia	<3 times/day vs none	OR	0.83 (0.40; 1.74)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
			≥3 times/day vs none		1.27 (0.50; 3.21)	
		Egypt	<3 times/day vs none		0.59 (0.47; 0.76)	Age, sex, physical activity, sedentary behaviour, being bullied
			≥3 times/day vs none		0.82 (0.49; 1.35)	
		Saint Vincent and Grenadines	<3 times/day vs none		0.71 (0.42; 1.19)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
			≥3 times/day vs none		0.76 (0.43; 1.35)	
		Djibouti	<3 times/day vs none		0.99 (0.57; 1.72)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status
			≥3 times/day vs none		1.17 (0.73; 1.89)	
		Morocco	<3 times/day vs none		0.43 (0.12; 1.56)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
			≥3 times/day vs none		0.60 (0.16; 2.25)	
		Myanmar	<3 times/day vs none		0.53 (0.17; 1.63)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
			≥3 times/day vs none		0.69 (0.21; 2.24)	
		Zambia	<3 times/day vs none		0.86 (0.47; 1.55)	Age, sex, physical activity, sedentary behaviour, being bullied, alcohol intake
			≥3 times/day vs none		1.10 (0.60; 2.01)	
		United Republic of Tanzania	<3 times/day vs none		0.43 (0.26; 0.69)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
			≥3 times/day vs none		0.56 (0.31; 0.99)	
		Venezuela	<3 times/day vs none		0.79 (0.59; 1.06)	Age, sex, physical activity, sedentary behaviour, being bullied, alcohol intake
			≥3 times/day vs none		0.73 (0.55; 0.97)	
		Grenada	<3 times/day vs none		0.68 (0.45; 1.03)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
			≥3 times/day vs none		0.85 (0.54; 1.35)	
		Lebanon	<3 times/day vs none		0.55 (0.42; 0.73)	Age, sex, being bullied, alcohol intake
			≥3 times/day vs none		0.57 (0.41; 0.78)	
		China	<3 times/day vs none		0.42 (0.21; 0.87)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
			≥3 times/day vs none		0.44 (0.22; 0.88)	
		Indonesia	<3 times/day vs none		0.56 (0.30; 1.04)	Age, sex, physical activity, sedentary

			≥3 times/day vs none		0.58 (0.30; 1.15)	behaviour, being bullied, smoking status, alcohol intake
		Thailand	<3 times/day vs none		1.19 (0.53; 2.67)	Age, sex, physical activity, sedentary
			≥3 times/day vs none		1.13 (0.51; 2.51)	behaviour, being bullied, smoking status, alcohol intake
		Uganda	<3 times/day vs none		0.85 (0.66; 1.10)	Age, sex, physical activity, sedentary
			≥3 times/day vs none		0.85 (0.57; 1.28)	behaviour, being bullied, smoking status, alcohol intake
		Tunisia	<3 times/day vs none		0.86 (0.64; 1.16)	Age, sex, physical activity, sedentary
			≥3 times/day vs none		0.82 (0.60; 1.14)	behaviour, being bullied, smoking status
		Botswana	<3 times/day vs none		0.80 (0.57; 1.13)	Age, sex, physical activity, sedentary
			≥3 times/day vs none		0.90 (0.60; 1.35)	behaviour, being bullied, smoking status, alcohol intake
		Sri Lanka	<3 times/day vs none		0.53 (0.34; 0.82)	Age, sex, physical activity, sedentary
			≥3 times/day vs none		0.55 (0.31; 0.99)	behaviour, being bullied
		India	<3 times/day vs none		1.14 (0.65; 1.99)	Age, sex, physical activity, sedentary
			≥3 times/day vs none		1.03 (0.62; 1.71)	behaviour, smoking status
		Seychelles	<3 times/day vs none		1.00 (0.86; 1.16)	Age, sex, physical activity, sedentary
			≥3 times/day vs none		0.88 (0.76; 1.03)	behaviour, being bullied, smoking status, alcohol intake
		Guyana	<3 times/day vs none		0.63 (0.26; 1.52)	Age, sex, physical activity, sedentary
			≥3 times/day vs none		0.71 (0.28; 1.78)	behaviour, being bullied, smoking status, alcohol intake
		Ecuador	<3 times/day vs none		0.69 (0.58; 0.84)	Age, sex, physical activity, sedentary
			≥3 times/day vs none		0.59 (0.48; 0.74)	behaviour, being bullied, smoking status, alcohol intake
		Jordan	<3 times/day vs none		1.01 (0.57; 0.81)	Age, sex, physical activity, sedentary
			≥3 times/day vs none		0.75 (0.38; 1.48)	behaviour, being bullied, smoking status
		Argentina	<3 times/day vs none		0.78 (0.57; 1.08)	Age, sex, physical activity, sedentary
			≥3 times/day vs none		0.50 (0.32; 0.77)	behaviour, being bullied, smoking status, alcohol intake
		Kenya	<3 times/day vs none		0.82 (0.47; 1.44)	Age, sex, physical activity, sedentary
			≥3 times/day vs none		0.76 (0.43; 1.34)	behaviour, being bullied, smoking status, alcohol intake
Park et al. 2018[103]	multiple logistic regression	N/A	high (once or more every day) vs. low-frequency consumption group (less than once per day)	OR	1.01 (0.97; 1.06)	sex, school grade, residential area, socioeconomic status, and other dietary behaviours (skipping breakfast, milk 2 or more times/day, fast food 3 times or more per week, soft drinks 3 times or more per

						week, vegetables (3 times or more per day))
Vegetables and fruit						
Hoare et al. 2014[99]	multivariable logistic regression	females	did not meet WHO recommendations of 400g/day vs. met WHO recommendations	OR	1.07 (SE 0.06)	stratified by gender; adjusted for age, parent's level of education, and school the participant attended
		males			0.98 (SE 0.09)	
Hoare et al. 2016[104]	cross-sectional analysis: simple logistic regression	females	did not meet WHO recommendations of 400g/day vs. met WHO recommendations	OR	0.85 (0.54; 1.34)	stratified by gender; no other covariates controlled for in data analysis
		males			0.87 (0.39; 1.96)	
	longitudinal analysis: multivariate linear regression	females	did not meet the recommendations at baseline → did not meet the recommendations at follow up	β	-0.62 (-2.32; 1.07)	stratified by gender; adjusted for school and parental education
			met the recommendations at baseline → did not meet the recommendations at follow up		-1.2 (-3.31; 0.91)	
			did not meet the recommendations at baseline → met the recommendations at follow up		-1.3 (-3.22; 0.62)	
		males	did not meet the recommendations at baseline → did not meet the recommendations at follow up		0.46 (-0.89; 1.81)	
			met the recommendations at baseline → did not meet the recommendations at follow up		-0.55 (-2.03; 0.93)	
			did not meet the recommendations at baseline → met the recommendations at follow up		0.62 (-0.8; 2.04)	
Ming-wei Liu et al.[102]	multivariable logistic regression	Saint Lucia	<5 vs 5 or more servings of fruit and vegetable per day	OR	0.78 (0.44; 1.38)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
		Egypt			0.81 (0.58; 1.14)	Age, sex, physical activity, sedentary behaviour, being bullied

	Saint Vincent and Grenadines	0.85 (0.53; 1.36)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
	Djibouti	0.88 (0.63; 1.21)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status
	Morocco	0.88 (0.72; 1.08)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
	Myanmar	0.89 (0.46; 1.72)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
	Zambia	0.94 (0.63; 1.40)	Age, sex, physical activity, sedentary behaviour, being bullied, alcohol intake
	United Republic of Tanzania	0.97 (0.64; 1.50)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
	Venezuela	1.00 (0.73; 1.37)	Age, sex, physical activity, sedentary behaviour, being bullied, alcohol intake
	Grenada	1.01 (0.73; 1.40)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
	Lebanon	1.03 (0.87; 1.23)	Age, sex, being bullied, alcohol intake
	China	1.03 (0.87; 1.23)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
	Indonesia	1.06 (0.87; 1.30)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
	Thailand	1.07 (0.79; 1.46)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
	Uganda	1.11 (0.78; 1.58)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
	Tunisia	1.14 (0.90; 1.44)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status
	Botswana	1.15 (0.81; 1.63)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status,

						alcohol intake
		Sri Lanka			1.20 (0.88; 1.64)	Age, sex, physical activity, sedentary behaviour, being bullied
		India			1.22 (0.95; 1.56)	Age, sex, physical activity, sedentary behaviour, smoking status
		Seychelles			1.27 (1.18; 1.36)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
		Guyana			1.31 (0.76; 2.26)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
		Ecuador			1.39 (1.07; 1.81)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
		Jordan			1.41 (1.08; 1.83)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status
		Argentina			1.46 (0.84; 2.54)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
		Kenya			1.56 (1.02; 2.38)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
Winpenny et al. 2018[40]	cross sectional analysis: multivariable linear regression	total	servings/day	β	-0.40 (-0.71; -0.10)	unadjusted
					-0.35 (-0.65; -0.05)	sex, SES
					-0.22 (-0.51; 0.08)	sex, SES, smoking level, alcohol consumption, physical activity, sleep
					-0.07 (-0.28; 0.14)	stratified by gender; adjusted for sex, SES, smoking level, level of alcohol consumption, PA, sleep, friendship quality, self-esteem, family functioning, percentage body fat, medication use, total energy intake
		females			0.03 (-0.28; 0.33)	
		males			-0.19 (-0.47; 0.1)	
	longitudinal analysis: multivariable linear	total			0.11 (-0.16; 0.38)	unadjusted
					0.17 (-0.10; 0.45)	sex, SES

	regression				0.16 (-0.12; 0.43)		sex, SES, smoking level, alcohol consumption, physical activity, sleep
					0.14 (-0.15; 0.43)		stratified by gender; adjusted for sex, SES, smoking level, level of alcohol consumption, PA, sleep, friendship quality, self-esteem, family functioning, percentage body fat, medication use, total energy intake, Mood and Feelings Questionnaire score at baseline
		females			0.21 (-0.22; 0.64)		
		males			0.06 (-0.32; 0.44)		
Anxiety							
Fruit							
Arat 2017[96]	binomial logistic regression	Botswana	high (≥1 time/ day) vs. low (6 times or less during the past 7 days)	OR	1.1 (1.06; 1.14)		age, gender, bullying, close friends, parental control, hunger (proxy for social status)
		Kenya			1.28 (1.26; 1.29)		
		Seychelles			1.34 (1.07; 1.67)		
		Uganda			1.45 (1.41; 1.48)		
		Tanzania			0.87 (0.8; 0.94)		
		Zambia			1.33 (1.3; 1.36)		
Ming-wei Liu et al.[102]	multivariable logistic regression	Saint Lucia	<2 times/day vs. none	OR	0.60 (0.27; 1.34)		Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
			≥2 times/day vs. none		0.74 (0.35; 1.54)		
		Egypt	<2 times/day vs. none		0.81 (0.46; 1.43)		Age, sex, physical activity, sedentary behaviour, being bullied
			≥2 times/day vs. none		1.25 (0.74; 2.11)		
		Saint Vincent and Grenadines	<2 times/day vs. none		0.88 (0.37; 2.07)		Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
			≥2 times/day vs. none		0.95 (0.39; 2.34)		
		Djibouti	<2 times/day vs. none		0.74 (0.43; 1.28)		Age, sex, physical activity, sedentary behaviour, being bullied, smoking status
			≥2 times/day vs. none		0.64 (0.38; 1.07)		
		Morocco	<2 times/day vs. none		0.41 (0.15; 1.11)		Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
			≥2 times/day vs. none		0.34 (0.13; 0.91)		
		Myanmar	<2 times/day vs. none		0.82 (0.26; 2.63)		Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
			≥2 times/day vs. none		0.78 (0.23; 2.60)		
		Zambia	<2 times/day vs. none		1.12 (0.65; 1.93)		Age, sex, physical activity, sedentary behaviour, being bullied, alcohol intake
			≥2 times/day vs. none		0.84 (0.49; 1.44)		
		United Republic of	<2 times/day vs. none		0.62 (0.22; 1.73)		Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
			≥2 times/day vs. none		0.30 (0.14; 0.65)		

Tanzania				
Venezuela	<2 times/day vs. none		0.55 (0.34; 0.89)	Age, sex, physical activity, sedentary
	≥2 times/day vs. none		0.52 (0.32; 0.84)	behaviour, being bullied, alcohol intake
Grenada	<2 times/day vs. none		1.16 (0.58; 2.30)	Age, sex, physical activity, sedentary
	≥2 times/day vs. none		0.96 (0.52; 1.78)	behaviour, being bullied, smoking status, alcohol intake
Lebanon	<2 times/day vs. none		0.88 (0.51; 1.51)	Age, sex, being bullied, alcohol intake
	≥2 times/day vs. none		0.84 (0.52; 1.37)	
China	<2 times/day vs. none		0.49 (0.34; 0.71)	Age, sex, physical activity, sedentary
	≥2 times/day vs. none		0.57 (0.37; 0.87)	behaviour, being bullied, smoking status, alcohol intake
Indonesia	<2 times/day vs. none		0.53 (0.27; 1.01)	Age, sex, physical activity, sedentary
	≥2 times/day vs. none		0.54 (0.31; 0.94)	behaviour, being bullied, smoking status, alcohol intake
Thailand	<2 times/day vs. none		0.66 (0.39; 1.12)	Age, sex, physical activity, sedentary
	≥2 times/day vs. none		0.59 (0.31; 1.11)	behaviour, being bullied, smoking status, alcohol intake
Uganda	<2 times/day vs. none		0.62 (0.44; 0.87)	Age, sex, physical activity, sedentary
	≥2 times/day vs. none		0.63 (0.35; 1.13)	behaviour, being bullied, smoking status, alcohol intake
Tunisia	<2 times/day vs. none		0.41 (0.27; 0.61)	Age, sex, physical activity, sedentary
	≥2 times/day vs. none		0.43 (0.31; 0.59)	behaviour, being bullied, smoking status
Botswana	<2 times/day vs. none		0.82 (0.55; 1.22)	Age, sex, physical activity, sedentary
	≥2 times/day vs. none		0.75 (0.49; 1.14)	behaviour, being bullied, smoking status, alcohol intake
Sri Lanka	<2 times/day vs. none		0.35 (0.20; 0.62)	Age, sex, physical activity, sedentary
	≥2 times/day vs. none		0.43 (0.26; 0.70)	behaviour, being bullied
India	<2 times/day vs. none		0.54 (0.37; 0.78)	Age, sex, physical activity, sedentary
	≥2 times/day vs. none		0.51 (0.34; 0.78)	behaviour, smoking status
Seychelles	<2 times/day vs. none		0.62 (0.38; 1.004)	Age, sex, physical activity, sedentary
	≥2 times/day vs. none		0.58 (0.36; 0.91)	behaviour, being bullied, smoking status, alcohol intake
Guyana	<2 times/day vs. none		0.55 (0.25; 1.21)	Age, sex, physical activity, sedentary
	≥2 times/day vs. none		0.59 (0.24; 1.42)	behaviour, being bullied, smoking status, alcohol intake
Ecuador	<2 times/day vs. none		0.55 (0.37; 0.80)	Age, sex, physical activity, sedentary
	≥2 times/day vs. none		0.61 (0.41; 0.91)	behaviour, being bullied, smoking status, alcohol intake
Jordan	<2 times/day vs. none		0.59 (0.38; 0.93)	Age, sex, physical activity, sedentary

			≥2 times/day vs. none		0.60 (0.31; 1.14)	behaviour, being bullied, smoking status
		Argentina	<2 times/day vs. none		0.35 (0.16; 0.77)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
			≥2 times/day vs. none		0.62 (0.28; 1.37)	
		Kenya	<2 times/day vs. none		0.52 (0.36; 0.75)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
			≥2 times/day vs. none		0.60 (0.42; 0.86)	
Vegetables						
Arat 2017[96]	binomial logistic regression	Botswana	high (≥1 time/ day) vs. low (6 times or less during the past 7 days)	OR	1.15 (1.11; 1.2)	age, gender, bullying, close friends, parental control, hunger (proxy for social status)
		Kenya			0.99 (0.98; 1.01)	
		Seychelles			1.88 (1.52; 2.32)	
		Uganda			1.58 (1.55; 1.62)	
		Tanzania			0.7 (0.64; 0.77)	
		Zambia			0.97 (0.94; 0.99)	
Ming-wei Liu et al.[102]	multivariable logistic regression	Saint Lucia	<3 times/day vs. none	OR	0.72 (0.37; 1.43)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
			≥3 times/day vs. none		1.37 (0.62; 3.02)	
		Egypt	<3 times/day vs. none		0.64 (0.36; 1.17)	Age, sex, physical activity, sedentary behaviour, being bullied
			≥3 times/day vs. none		0.79 (0.35; 1.80)	
		Saint Vincent and Grenadines	<3 times/day vs. none		0.50 (0.27; 0.92)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
			≥3 times/day vs. none		0.88 (0.51; 1.51)	
		Djibouti	<3 times/day vs. none		0.49 (0.27; 0.87)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status
			≥3 times/day vs. none		0.64 (0.32; 1.29)	
		Morocco	<3 times/day vs. none		0.48 (0.22; 1.06)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
			≥3 times/day vs. none		0.55 (0.26; 1.15)	
		Myanmar	<3 times/day vs. none		0.42 (0.07; 2.43)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
			≥3 times/day vs. none		0.18 (0.03; 1.30)	
		Zambia	<3 times/day vs. none		1.14 (0.75; 1.74)	Age, sex, physical activity, sedentary behaviour, being bullied, alcohol intake
			≥3 times/day vs. none		1.45 (0.94; 2.24)	
		United Republic of Tanzania	<3 times/day vs. none		0.57 (0.20; 1.61)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
			≥3 times/day vs. none		1.22 (0.57; 2.64)	
		Venezuela	<3 times/day vs. none		0.95 (0.62; 1.44)	Age, sex, physical activity, sedentary behaviour, being bullied, alcohol intake
			≥3 times/day vs. none		1.58 (0.88; 2.85)	

Grenada	<3 times/day vs. none	0.68 (0.34; 1.35)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
	≥3 times/day vs. none	0.74 (0.36; 1.52)	
Lebanon	<3 times/day vs. none	0.49 (0.32; 0.74)	Age, sex, being bullied, alcohol intake
	≥3 times/day vs. none	0.57 (0.34; 0.95)	
China	<3 times/day vs. none	0.29 (0.11; 0.77)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
	≥3 times/day vs. none	0.28 (0.10; 0.80)	
Indonesia	<3 times/day vs. none	1.16 (0.35; 3.82)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
	≥3 times/day vs. none	0.99 (0.28; 3.49)	
Thailand	<3 times/day vs. none	1.59 (0.45; 5.69)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
	≥3 times/day vs. none	1.66 (0.49; 5.67)	
Uganda	<3 times/day vs. none	0.71 (0.48; 1.04)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
	≥3 times/day vs. none	1.11 (0.60; 2.05)	
Tunisia	<3 times/day vs. none	0.74 (0.46; 1.19)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status
	≥3 times/day vs. none	0.94 (0.56; 1.59)	
Botswana	<3 times/day vs. none	0.81 (0.47; 1.41)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
	≥3 times/day vs. none	1.13 (0.61; 2.09)	
Sri Lanka	<3 times/day vs. none	0.61 (0.15; 2.45)	Age, sex, physical activity, sedentary behaviour, being bullied
	≥3 times/day vs. none	0.69 (0.20; 2.36)	
India	<3 times/day vs. none	1.06 (0.55; 2.05)	Age, sex, physical activity, sedentary behaviour, smoking status
	≥3 times/day vs. none	1.07 (0.52; 2.20)	
Seychelles	<3 times/day vs. none	0.58 (0.41; 0.82)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
	≥3 times/day vs. none	0.60 (0.42; 0.86)	
Guyana	<3 times/day vs. none	0.79 (0.30; 1.12)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
	≥3 times/day vs. none	1.36 (0.43; 4.27)	
Ecuador	<3 times/day vs. none	0.61 (0.42; 0.88)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
	≥3 times/day vs. none	0.70 (0.48; 1.002)	
Jordan	<3 times/day vs. none	0.86 (0.37; 1.97)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status
	≥3 times/day vs. none	0.67 (0.25; 1.82)	
Argentina	<3 times/day vs. none	0.97 (0.54; 1.76)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status,
	≥3 times/day vs. none	0.41 (0.15; 1.16)	

						alcohol intake
		Kenya	<3 times/day vs. none		0.94 (0.47; 1.88)	Age, sex, physical activity, sedentary behaviour, being bullied, smoking status, alcohol intake
			≥3 times/day vs. none		1.12 (0.56; 2.27)	
Depression and anxiety						
Vegetables and fruit						
McMartin et al. 2012[105]	negative binomial regression	N/A	2nd tertile vs 1st tertile	IRR	1.06 (0.68; 1.66)	energy intake
			3rd tertile vs 1st tertile		1.15 (0.73; 1.81)	
			2nd tertile vs 1st tertile		1.04 (0.71; 1.53)	energy intake, gender, household income, parental marital status and education, body weight status, PA and geographic area
			3rd tertile vs 1st tertile		1.25 (0.8; 1,99)	

Appendices

Appendix D

PRISMA-S Checklist

INFORMATION SOURCES AND METHODS			
Database name	1	Name each individual database searched, stating the platform for each.	21
Multi-database searching	2	If databases were searched simultaneously on a single platform, state the name of the platform, listing all of the databases searched. (Cochrane Library (Reviews and Trials)	21
Study registries	3	List any study registries searched.	22 (e.g., PROSPERO)
Online resources and browsing	4	Describe any online or print source purposefully searched or browsed (e.g., tables of contents, print conference proceedings, web sites), and how this was done.	We pilot searched several relevant websites, however, our search did not yield any relevant publications.
Citation searching	5	Indicate whether cited references or citing references were examined, and describe any methods used for locating cited/citing references (e.g., browsing reference lists, using a citation index, setting up email alerts for references citing included studies).	21-22
Contacts	6	Indicate whether additional studies or data were sought by contacting authors, experts, manufacturers, or others.	22
Other methods	7	Describe any additional information sources or search methods used.	N/A
SEARCH STRATEGIES			
Full search strategies	8	Include the search strategies for each database and information source, copied and pasted exactly as run.	Appendix A
Limits and restrictions	9	Specify that no limits were used, or describe any limits or restrictions applied to a search (e.g., date or time period, language, study design) and provide justification for their use.	1-2
Search filters	10	Indicate whether published search filters were used (as originally designed or modified), and if so, cite the filter(s) used.	Appendix A

Prior work	11	Indicate when search strategies from other literature reviews were adapted or reused for a substantive part or all of the search, citing the previous review(s).	N/A
Updates	12	Report the methods used to update the search(es) (e.g., rerunning searches, email alerts).	21-22
Dates of searches	13	For each search strategy, provide the date when the last search occurred.	Appendix A
PEER REVIEW			
Peer review	14	Describe any search peer review process.	N/A
MANAGING RECORDS			
Total Records	15	Document the total number of records identified from each database and other information sources.	Appendix A
Deduplication	16	Describe the processes and any software used to deduplicate records from multiple database searches and other information sources.	22

PRISMA-S: An Extension to the PRISMA Statement for Reporting Literature Searches in Systematic Reviews. Rethlefsen ML, Kirtley S, Waffenschmidt S, Ayala AP, Moher D, Page MJ, Koffel JB, PRISMA-S Group. Last updated February 27, 2020.

Appendix E

Prospective cohort studies on the diet–mental health relationship in adolescents that informed the development of the directed acyclic graph and covariates adjusted for in these studies.

		Esteban-Gonzalo et al.[127]	**McMartin et al.[105]**	**Wilson et al.[128]**	**Winpenny et al.[40]**	**Wu et al.[129]**	**Jacka et al.[130]**	**Jacka et al.[131]**
Sex		effect modifier*	✓	✓	effect modifier	✓	✓	✓
Mental health at baseline (T_0)		✓	-	✓	-	-	-	✓
Age		✓	-	✓	-	-	-	✓
SES	area-level SES	-	-	✓	✓	-	✓	✓
	household income	-	✓	-	-	✓	-	-
	family affluence	✓	-	-	-	-	-	-
	parental education	-	✓	-	-	✓	-	-
	parental marital status	-	✓	-	-	-	-	-
Weight status	BMI	✓	✓	✓	-	✓	-	✓
	% body fat	-	-	-	✓	-	-	-
Lifestyle behaviours	physical activity	-	✓	✓	✓	-	✓	✓
	sedentary behaviour	-	-	-	-	✓	-	-
	sleep	-	-	-	✓	-	-	-
	smoking	-	-	✓	✓	-	✓	-
	alcohol	-	-	✓	✓	-	✓	-
	drug use	-	-	-	-	-	✓	-
Eating behaviours	breakfast eating	-	-	✓	-	-	-	-
	dieting	-	-	-	-	-	✓	✓
Social support	friendship quality	-	-	-	✓	-	-	-
	family social support	-	-	-	-	-	✓	-
	family functioning	-	-	-	✓	-	-	-

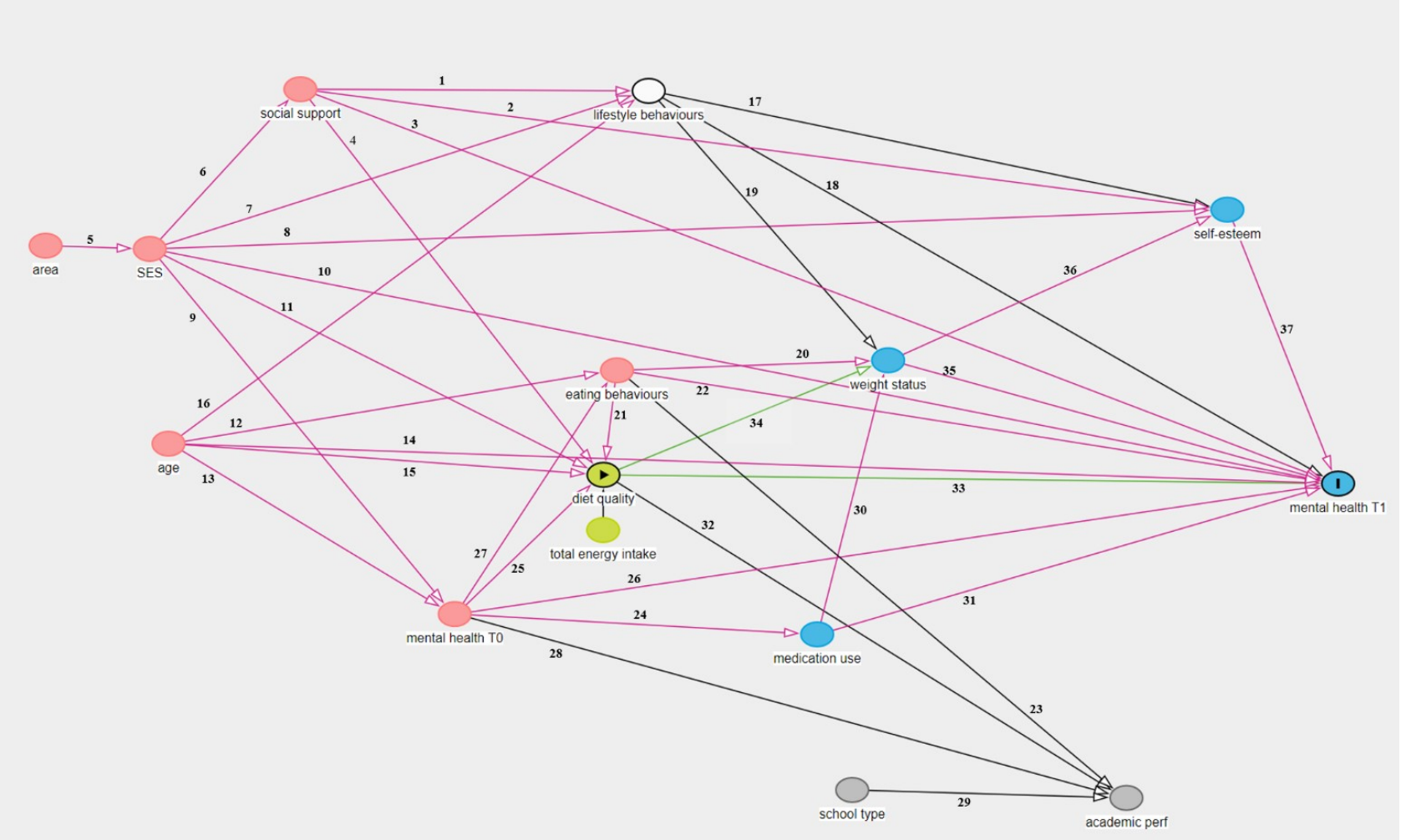
parental conflict	-	-	-	-	-	✓	-
Self-esteem	-	-	-	✓	✓	-	-
Geographic area	-	✓	-	-	✓	-	-
School type	-	-	✓	-	-	-	-
Academic performance	-	-	✓	-	-	-	-
Total energy intake	-	✓	-	✓	-	-	-
Medication use	-	-	-	✓	-	-	-

*Studies that conducted sex-based analyses treated sex as a potential effect modifier rather than a confounder.

Appendices

Appendix F

Directed acyclic graph for the diet–mental health relationship.



*Each edge is supported by a reference (Table S2).

Appendix G

Sources supporting each edge included in the final DAG.

#	Directed edge	References
1	Social support → lifestyle behaviours	Khosravi A, Mohammadpoorasl A, Holakouie-Naieni K, Mahmoodi M, Pouyan AA, Mansournia MA. Causal effect of self-esteem on cigarette smoking stages in adolescents: coarsened exact matching in a longitudinal study. *Osong Public Health Res Perspect*. 2016 Dec;7(6):341–5. doi:10.1016/j.phrp.2016.10.003 Fosco G, Feinberg M. Interparental conflict and long-term adolescent substance use trajectories: the role of adolescent threat appraisals. *J Fam Psychol*. 2018 Mar;32(2):175-185. doi:10.1037/fam0000356 Osgood DW, Ragan DT, Wallace L, Gest SD, Feinberg ME, Moody J. Peers and the emergence of alcohol use: influence and selection processes in adolescent friendship networks. *J Res Adolesc*. 2013 Sep 1;23(3). doi:10.1111/jora.12059 Leyton, M., & Stewart, S. (Eds.). Substance abuse in Canada: childhood and adolescent pathways to substance use disorders. Ottawa, ON: Canadian Centre on Substance Abuse. 2014 [cited Aug 17, 2022] Available from: https://www.ccsa.ca/sites/default/files/2019-04/CCSA-Child-Adolescent-Substance-Use-Disorders-Report-2014-en.pdf [general population] Harris, M. A., & Orth, U. (2020). The link between self-esteem and social relationships: a meta-analysis of longitudinal studies. *J Pers Soc Psychol.* 2020 Dec;119(6):1459-1477. doi:10.1037/pspp0000265
2	social support → self-esteem	Maunder R, Monks CP. Friendships in middle childhood: links to peer and school identification, and general self-worth. *Br J Dev Psychol*. 2019 Jun;37(2):211–29. doi:10.1111/bjdp.12268

3	social support → mental health	[general population] Howick J, Kelly P, Kelly M. Establishing a causal link between social relationships and health using the Bradford Hill Guidelines. *SSM Popul Health*. 2019 May 4;8:100402. doi:10.1016/j.ssmph.2019.100402 Willems YE, Zeeuw EL de, Beijsterveldt CEM van, Boomsma DI, Bartels M, Finkenauer C. Out of control: examining the association between family conflict and self-control in adolescence in a genetically sensitive design. *J Am Acad Child Adolesc Psychiatry*. 2020 Feb;59(2):254-262. doi:10.1016/j.jaac.2019.02.017 Breslend NL, Parent J, Forehand R, Compas BE, Thigpen JC, Hardcastle E. Parental depressive symptoms and youth internalizing and externalizing problems: the moderating role of interparental conflict. *J Fam Violence*. 2016 Oct;31(7):823-831. doi:10.1007/s10896-016-9817-z
4	social support → diet	Salvy SJ, de la Haye K, Bowker JC, Hermans RC. Influence of peers and friends on children's and adolescents' eating and activity behaviors. *Physiol Behav*. 2012 Jun 6;106(3):369-78. doi:10.1016/j.physbeh.2012.03.022
5	geographic area →socio-economic status	Logical reasoning: rural and urban areas present different educational and job opportunities, and thus affect socio-economic status.
6	socio-economic status → social support	[older adults] Ashida T, Fujiwara T, Kondo K. Childhood socio-economic status and social integration in later life: Results of the Japan Gerontological Evaluation Study. *SSM Popul Health*. 2022 Jun 1;18:101090. doi:10.1016/j.ssmph.2022.101090
7	socio-economic status → lifestyle behaviours	Armstrong S, Wong CA, Perrin E, Page S, Sibley L, Skinner A. Association of physical activity with income, race/ethnicity, and sex among adolescents and young adults in the United States: findings from the National Health and Nutrition Examination Survey, 2007-2016. *JAMA Pediatr*. 2018;172(8):732–40. doi:10.1001/jamapediatrics.2018.1273 [adults] Lee GB, Kim HC, Jeon YJ, Jung SJ. Association between socio-economic status and longitudinal sleep quality patterns mediated by depressive symptoms.

		Sleep. 2021 Aug 13;44(8):zsab044. doi:10.1093/sleep/zsab044
8	socio-economic status → self-esteem	Cooper K, Stewart K. Does household income affect children's outcomes? A systematic review of the evidence. *Child Ind Res*. 2021 Jun 1;14(3):981–1005. doi:10.1007/s12187-020-09782-0
9, 10	socioeconomic status → mental health (baseline (9)/follow-up (10))	Ge T. Effect of socio-economic status on children's psychological wellbeing in China: the mediating role of family social capital. *J Health Psychol*. 2020 Jul 1;25(8):1118–27. doi:10.1177/1359105317750462 [general population] Hoffmann, R., Kröger, H. & Geyer, S. Social causation versus health selection in the life course: does their relative importance differ by dimension of SES? *Soc Indic Res*. 2019;141:1341–67. doi:10.1007/s11205-018-1871-x
11	socio-economic status → diet	Michels N, Vynckier L, Moreno L, Béghin L, O A, Forsner M, et al. Mediation of psychosocial determinants in the relation between socio-economic status and adolescents' diet quality. *Eur J Nutr*. 2018 Apr;57(3):951-63. doi: 10.1007/s00394-017-1380-8
12	age → eating behaviours	Canadian Pediatric Society. Dieting in adolescence. *Paediatr Child Health*. 2004;9(7):487-503. doi:10.1093/pch/9.7.487 Doggui R, Ward S, Johnson C, Bélanger M. Trajectories of eating behaviours during adolescence among Canadian youth. *Curr Dev Nutr*. 2021 Jun 7;5(Suppl 2):1025. doi:10.1093/cdn/nzab053_018
13, 14	age → mental health at baseline (13) and follow-up (14)	Thapar A, Collishaw S, Pine DS, Thapar AK. Depression in adolescence. *Lancet*. 2012 Mar 17;379(9820):1056–67. doi:10.1016/S0140-6736(11)60871-4
15	age → diet	Lipsky, L.M., Haynie, D.L., Liu, D. et al. Trajectories of eating behaviors in a nationally representative cohort of U.S. adolescents during the transition to young adulthood. *Int J Behav Nutr Phys Act.* 2015;12(138). doi:10.1186/s12966-015-0298-x

16	age → lifestyle behaviours	Kwon S, Janz KF, Letuchy EM, Burns TL, Levy SM. Developmental trajectories of physical activity, sports, and television viewing during childhood to young adulthood: Iowa bone development study. *JAMA Pediatr*. 2015;169(7):666–672. doi:10.1001/jamapediatrics.2015.0327
17	lifestyle behaviours → self-esteem	Boers E, Afzali MH, Newton N, Conrod P. Association of screen time and depression in adolescence. *JAMA Pediatrics*. 2019 Sep 1;173(9):853–9. doi:10.1001/jamapediatrics.2019.1759 Abi-Jaoude E, Naylor KT, Pignatiello A. Smartphones, social media use and youth mental health. *CMAJ*. 2020 Feb 10;192(6):E136–41. doi: 10.1503/cmaj.190434
18	lifestyle behaviours → mental health	Doré, I., Sylvester, B., Sabiston, C. et al. Mechanisms underpinning the association between physical activity and mental health in adolescence: a 6-year study. *Int J Behav Nutr Phys Act*. 2020 Jan 31;17(1):9. doi:10.1186/s12966-020-0911-5 Hale GE, Colquhoun L, Lancastle D, Lewis N, Tyson PJ. Review: Physical activity interventions for the mental health and wellbeing of adolescents – a systematic review. *Child Adolesc Ment Health*. 2021 Nov;26(4):357-368. doi:10.1111/camh.12485 [adults] Wootton RE, Richmond RC, Stuijfzand BG, Lawn RB, Sallis HM, Taylor GMJ, Hemani G, Jones HJ, Zammit S, Davey Smith G, Munafò MR. Evidence for causal effects of life-time smoking on risk for depression and schizophrenia: a Mendelian randomisation study. *Psychol Med*. 2020 Oct;50(14):2435-43. doi:10.1017/S0033291719002678 Fergusson DM, Boden JM, Horwood LJ. Tests of causal links between alcohol abuse or dependence and major depression. *Arch Gen Psychiatry*. 2009 Mar;66(3):260-6. doi:10.1001/archgenpsychiatry.2008.543 Vermeulen MCM, van der Heijden KB, Kocevska D, Treur JL, Huppertz C, van Beijsterveldt CEM, Boomsma DI, Swaab H, Van Someren EJW, Bartels M. Associations of sleep with psychological problems and wellbeing in adolescence:

		causality or common genetic predispositions? *J Child Psychol Psychiatry*. 2021 Jan;62(1):28-39. doi:10.1111/jcpp.13238 Kelly Y, Zilanawala A, Booker C, Sacker A. Social media use and adolescent mental health: findings from the UK Millennium Cohort Study. *EClinicalMedicine*. 2019 Jan 4;6:59-68. doi:10.1016/j.eclinm.2018.12.005
19	lifestyle behaviours → weight status	Richmond RC, Davey Smith G, Ness AR, den Hoed M, McMahon G, Timpson NJ (2014) Assessing causality in the association between child adiposity and physical activity levels: a Mendelian randomization analysis. *PLoS Med*. 2014 Mar 18;11(3):e1001618. doi:10.1371/journal.pmed.1001618 [general population] Taylor AE, Richmond RC, Palviainen T, et al. The effect of body mass index on smoking behaviour and nicotine metabolism: a Mendelian randomization study. *Hum Mol Genet*. 2019 Apr 15;28(8):1322-1330. doi:10.1093/hmg/ddy434 [general population] Traversy G, Chaput JP. Alcohol consumption and obesity: an update. *Curr Obes Rep*. 2015 Mar;4(1):122-30. doi:10.1007/s13679-014-0129-4 Do YK. Causal effect of sleep duration on body weight in adolescents. *Epidemiology*. 2019 Nov;30(6):876-884. doi:10.1097/EDE.0000000000001086 [adults] Helajärvi H, Rosenström T, Pahkala K, Kähönen M, Lehtimäki T, Heinonen OJ, et al. Exploring causality between TV viewing and weight change in young and middle-aged adults. the cardiovascular risk in Young Finns Study. *PLoS One*. 2014 Jul 16;9(7):e101860. doi:10.1371/journal.pone.0101860
20	eating behaviours → weight status	Logical reasoning (Dieting in adolescence. *Paediatr Child Health*. 2004 Sep;9(7):487-503. doi:10.1093/pch/9.7.487).
21	eating behaviours → diet quality	Logical reasoning
22	eating behaviours → mental	[adults] Haghighatdoost F, Feizi A, Esmaillzadeh A, Keshteli AH, Afshar H, Adibi

	health	P. Breakfast skipping alone and in interaction with inflammatory based quality of diet increases the risk of higher scores of psychological problems profile in a large sample of Iranian adults. *J Nutr Sci*. 2021 Feb 16;10:e10. doi:10.1017/jns.2020.62 Agathão BT, Cunha DB, Sichieri R, Lopes CS. The role of family meal frequency in common mental disorders in children and adolescents over eight months of follow-up. *PLoS One*. 2021 Feb 4;16(2):e0243793. doi:10.1371/journal.pone.0243793
23	eating behaviours → academic performance	Ptomey LT, Steger FL, Schubert MM, Lee J, Willis EA, Sullivan DK, et al. Breakfast intake and composition is associated with superior academic achievement in elementary school children. *J Am Coll Nutr*. 2016 May-Jun;35(4):326-33. doi:10.1080/07315724.2015
24	mental health at baseline → medication use	Logical reasoning: existing mental health issues increase the probability of taking medications to treat mental health issues.
25	mental health at baseline → diet quality	Logical reasoning: mental health problems might affect eating habits and behaviours, thus resulting in the changes to diet quality.
26	mental health at baseline → mental health at follow-up	Otto C, Reiss F, Voss C, Wüstner A, Meyrose AK, Hölling H, Ravens-Sieberer U. Mental health and wellbeing from childhood to adulthood: design, methods and results of the 11-year follow-up of the BELLA study. *Eur Child Adolesc Psychiatry*. 2021 Oct;30(10):1559-77. doi:10.1007/s00787-020-01630-4
27	mental health at baseline → eating behaviours	Logical reasoning: mental health problems might affect eating habits (e.g., increased snacking, skipping breakfast).
28	mental health at baseline → academic performance	Agnafors S, Barmark M, Sydsjö G. Mental health and academic performance: a study on selection and causation effects from childhood to early adulthood. *Soc Psychiatry Psychiatr Epidemiol*. 2021 May;56(5):857-866. doi:10.1007/s00127-020-01934-5
29	school type → academic	Logical reasoning: school type (e.g., public vs. private) might affect academic

	performance	performance.
30	medication use → weight status	Schwartz BS, Glass TA, Pollak J, Hirsch AG, Bailey-Davis L, Moran TH, Bandeen-Roche K. Depression, its comorbidities and treatment, and childhood body mass index trajectories. *Obesity (Silver Spring)*. 2016 Dec;24(12):2585-92. doi:10.1002/oby.21627
31	medication use → mental health at follow-up	Logical reasoning: medications that aim to treat mental health issues would result (assuming they are effective) in the improved mental health at follow up.
32	diet quality → academic performance	Florence MD, Asbridge M, Veugelers PJ. Diet quality and academic performance. *J Sch Health*. 2008;78(4):209–15. doi:10.1111/j.1746-1561.2008.00288.x
33	diet quality → mental health at follow-up	The focal relationship under investigation.
34	diet quality → weight status	Logical reasoning: diet quality is one of the established causal risk factors for overweight and obesity in children and adolescents.
35	weight status → mental health at follow-up	Carsley S, Pope E, Tu K, Parkin PC, Toulany A, Birken CS. Association between weight status and mental health service utilization in children and adolescents. *J Can Acad Child Adolesc Psychiatry*. 2020 Nov;29(4):229-40
36	weight status → self-esteem	Lowry KW, Sallinen BJ, Janicke DM. The effects of weight management programs on self-esteem in pediatric overweight populations. *J Pediatr Psychol*. 2007 Nov-Dec;32(10):1179-95. doi:10.1093/jpepsy/jsm048
37	self-esteem → mental health at follow-up	Orth U, Robins RW, Widaman KF, Conger RD. Is low self-esteem a risk factor for depression? Findings from a longitudinal study of Mexican-origin youth. *Dev Psychol*. 2014 Feb;50(2):622-33. doi:10.1037/a0033817

Appendices

Appendix H

Characteristics of included (n=13,887) and excluded (n=15,096) participants at baseline (2017/18) in the COMPASS data.

	Included			**Excluded**		
	Total	**Female**	**Male**	**Total**	**Female**	**Male**
Depressive symptoms						
CES-D-R score, median (mad)	7.0 (4.4)	8.0 (5.9)	6.0 (4.4)	6.00 (4.4)	8.00 (5.9)	6.00 (4.4)
Yes (10 or higher), n (%)	4,504 (32.4)	3,028 (40.7)	1,476 (22.9)	3,543 (31.8)	2,376 (40.0)	1,167 (22.4)
Missing, n (%)	0 (0)	0 (0)	0 (0)	3,944 (26.1)	2,021 (25.4)	1,923 (26.9)
Anxiety symptoms						
GAD-7 score, median (mad)	5.0 (4.4)	6.0 (5.9)	3.0 (4.4)	4.0 (4.4)	6.0 (5.9)	3.0 (4.4)
Yes (10 or higher), n (%)	3,157 (22.7)	2,311 (31.0)	846 (13.1)	2,783 (21.2)	2,025 (29.3)	758 (12.2)
Missing, n (%)	0 (0)	0 (0)	0 (0)	1,985 (13.1)	1,054 (13.2)	931 (13.0)
Psychological wellbeing						
Flourishing score, median (mad)	32.0 (5.9)	32.0 (5.9)	33.0 (4.5)	32.0 (5.9)	32.0 (5.9)	33.0 (5.9)
Missing, n (%)	0 (0)	0 (0)	0 (0)	1,316 (8.7)	618 (7.8)	698 (9.8)
Vegetables and fruit (servings/day), median (mad)	3.0 (1.5)	3.0 (1.5)	3.0 (1.5)	3.0 (1.5)	3.0 (1.5)	3.0 (1.5)
Missing, n (%)	0 (0)	0 (0)	0 (0)	782 (5.2)	287 (3.6)	495 (6.9)
SSB (composite index), median (mad)	3.0 (2.9)	3.0 (2.9)	3.0 (2.9)	3.0 (2.9)	3.0 (2.9)	3.0 (2.9)
0	2,601 (18.7)	1,520 (20.4)	1,081 (16.8)	2,715 (18.4)	1,582 (19.9)	1,133 (15.8)
>0	11,286 (81.3)	5,928 (79.6)	5,358 (83.2)	11,761 (79.5)	6,264 (78.7)	5,807 (81.3)
Missing, n (%)	0 (0)	0 (0)	0 (0)	310 (2.1)	109 (1.4)	201 (2.8)
Sex, n (%)	-	7,448 (54)	6,439 (46)	-	7,955 (53)	7,141 (47)
Missing, n (%)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Age, mean (SD)	14.9 (1.2)	14.9 (1.2)	14.9 (1.1)	14.7 (1.2)	14.7 (1.2)	14.7 (1.2)
Missing, n (%)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Weekly spending money, n (%)						
$0	3,049 (22.0)	1,473 (19.8)	1,576 (24.5)	2,217 (14.7)	1,014 (12.7)	1,203 (16.8)
$1 to $20	4,851 (34.9)	2,709 (36.3)	2,142 (33.3)	3,519 (23.3)	1,824 (22.9)	1,695 (23.7)
$21 to $100	3,775 (27.2)	2,132 (28.7)	1,643 (25.5)	2,488 (16.5)	1,333 (16.8)	1,155 (16.2)

more than $100	2,212 (15.9)	1,134 (15.2)	1,078 (16.7)	1,486 (9.8)	697 (8.8)	789 (11.0)
Missing, n (%)	0 (0)	0 (0)	0 (0)	5,386 (35.7)	3,087 (38.8)	2,299 (32.3)
Weight loss attempt, n (%)	609 (4.4)	476 (6.4)	133 (2.1)	643 (4.3)	526 (6.6)	117 (1.6)
Missing, n (%)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Breakfast skipping, n (%)	7,287 (52.5)	3,522 (47.3)	3,765 (58.5)	7,551 (50.0)	3,671 (46.2)	3,880 (54.3)
Missing, n (%)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
MVPA (minutes), median (mad*)	90.0 (66.7)	83.6 (60.4)	100.7 (73.1)	90.0 (69.9)	79.3 (60.4)	100.71 (76.2)
Missing, n (%)	0 (0)	0 (0)	0 (0)	895 (5.9)	362 (4.6)	533 (7.5)
Screen time (hours/day), median (mad)	6.0 (3.3)	5.8 (3.3)	6.0 (3.3)	6.0 (3.3)	5.8 (3.3)	6.0 (3.3)
Missing, n (%)	0 (0)	0 (0)	0 (0)	2,682 (17.8)	1,369 (17.2)	1,313 (18.4)
Sleep (hours/day), median (mad)	7.8 (1.1)	7.5 (1.1)	8.0 (1.5)	8.0 (1.5)	8.0 (1.5)	8.0 (1.5)
Missing, n (%)	0 (0)	0 (0)	0 (0)	2,680 (17.8)	1,368 (17.2)	1,312 (18.4)
Current use of cigarettes, n (%)	672 (4.8)	330 (4.4)	342 (5.3)	1,028 (6.8)	485 (6.1)	543 (7.6)
Missing, n (%)	0 (0)	0 (0)	0 (0)	134 (0.9)	43 (0.5)	91 (1.3)
Current use of e-cigarettes, n (%)	2,364 (17.0)	1,104 (14.8)	1,260 (19.6)	2,906 (19.3)	1,281 (16.1)	1,625 (22.8)
Missing, n (%)	0 (0)	0 (0)	0 (0)	257 (1.7)	97 (1.2)	160 (2.2)
Current binge drinking, n (%)	1,611 (11.6)	827 (11.1)	784 (12.2)	1,735 (11.5)	856 (10.8)	879 (12.3)
Missing, n (%)	0 (0)	0 (0)	0 (0)	74 (0.5)	43 (0.5)	31 (0.4)
Current cannabis use, n (%)	1,016 (7.3)	504 (6.7)	512 (7.9)	1,237 (8.2)	546 (6.9)	691 (9.7)
Missing, n (%)	0 (0)	0 (0)	0 (0)	267 (1.8)	110 (1.4)	157 (2.2)
Supportive social relationships, n (%)						
(Strongly) agree	10,853 (78.1)	5,721 (76.8)	5,132 (79.7)	11,170 (74.0)	5,855 (73.6)	5,315 (74.4)
Neither/(Strongly) disagree	3,034 (21.9)	1,727 (23.2)	1,307 (20.3)	3,381 (22.4)	1,874 (23.6)	1,507 (21.1)
Missing, n (%)	0 (0)	0 (0)	0 (0)	545 (3.6)	226 (2.8)	319 (4.5)
Happy home life, n (%)						
(Strongly) agree	11,173 (80.5)	5,711 (76.7)	5,562 (86.4)	11,896 (78.8)	6,002 (75.5)	5,894 (82.5)
Neither/(Strongly) disagree	2,714 (19.5)	1,737 (23.3)	887 (13.6)	2,820 (18.7)	1,809 (22.7)	1,011 (14.2)
Missing, n (%)	0 (0)	0 (0)	0 (0)	380 (2.5)	144 (1.8)	236 (3.3)
Variables used in sensitivity analyses						
Self-concept score, mean (sd)	10.0 (4.4)	11.0 (4.4)	9.0 (4.4)	10.0 (4.4)	11.0 (4.4)	9.0 (4.4)
Missing, n (%)	0 (0)	0 (0)	0 (0)	426 (2.8)	148 (1.9)	278 (3.9)

Self-perceived weight status, n (%)						
Underweight	2,222 (16.0)	821 (11.0)	1,401 (21.8)	2,495 (16.5)	954 (12.0)	1,541 (21.6)
About right	8,427 (60.7)	4,714 (63.3)	3,713 (57.7)	8,824 (58.5)	4,884 (61.4)	3,940 (55.2)
Overweight	3,238 (23.3)	1,913 (25.7)	1,325 (20.6)	3,347 (22.2)	1,893 (23.8)	1,454 (20.4)
Missing, n (%)	0 (0)	0 (0)	0 (0)	430 (2.8)	224 (2.8)	206 (2.9)
Race/ethnicity, n (%)⁑						
White	10,818 (77.9)	5,837 (78.4)	4,981 (77.4)	11,600 (76.8)	6,161 (77.4)	5,439 (76.2)
Black	526 (3.8)	261 (3.5)	265 (4.1)	779 (5.2)	363 (4.6)	416 (5.8)
Asian	1,911 (13.8)	1,040 (14.0)	871 (13.5)	1,792 (11.9)	970 (12.2)	822 (11.5)
Hispanic	467 (3.4)	250 (3.4)	217 (3.4)	483 (3.2)	265 (3.3)	218 (3.1)
Other/Mixed	1,406 (10.1)	805 (10.8)	601 (9.3)	1,723 (11.4)	889 (11.2)	834 (11.7)
Missing, n (%)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Overall mark in a current/recent Math course, n (%)						
90-100%	3,664 (26.4)	2,097 (28.2)	1,567 (24.3)	2,917 (19.3)	1,659 (20.9)	1,258 (17.6)
80-89%	4,072 (29.3)	2,222 (29.8)	1,850 (28.7)	3,945 (26.1)	2,184 (27.5)	1,761 (24.7)
70-79%	3,077 (22.2)	1,584 (21.3)	1,493 (23.2)	3,265 (21.6)	1,670 (21.0)	1,595 (22.3)
60-69%	1,739 (12.5)	883 (11.9)	856 (13.3)	1,994 (13.2)	1,020 (12.8)	974 (13.6)
<60%	1,335 (9.6)	662 (8.8)	673 (10.5)	1,824 (12.1)	884 (11.1)	940 (13.2)
Missing, n (%)	0 (0)	0 (0)	0 (0)	1,151 (7.6)	538 (6.8)	613 (8.6)
Geographic area†, n (%)						
Census metropolitan areas	9,306 (67.0)	5,042 (67.7)	4,264 (66.2)	9,564 (63.4)	5,053 (63.5)	4,511 (63.2)
Census agglomerations	1,914 (13.8)	1,008 (13.5)	906 (14.1)	1,937 (12.8)	1,018 (12.8)	919 (12.9)
Small towns and rural areas	2,667 (19.2)	1,398 (18.8)	1,269 (19.7)	2,952 (19.6)	1,554 (19.5)	1,398 (19.6)
Missing, n (%)	0 (0)	0 (0)	0 (0)	643 (4.3)	330 (4.1)	313 (4.4)

⁑mad: median absolute deviation; SD: standard deviation.

⁑ proportions do not add up since participants could choose multiple ethnicities.

†Geographic area was classified according to population into census metropolitan areas (>100,000 population), census agglomerations (10,000 to 100,000), and small towns and rural areas (<10,000).

Appendices

Appendix I

Cross-sectional associations between fruit and vegetables intake, sugar-sweetened beverages consumption, self-concept (i.e., positive exposure control) and depressive and anxiety symptoms, and psychological wellbeing in COMPASS study (at baseline).

	Unadjusted	**Model 1***	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
	β (95% CI)	**β (95% CI)**	**β (95% CI)**	**β (95% CI)**	**β (95% CI)**	**β (95% CI)**	**β (95% CI)**
Depressive symptoms							
Exposures of interest							
Vegetables and fruit	**-0.30 (-0.34, -0.25)**	**-0.27 (-0.32, -0.22)**	**-0.18 (-0.23, -0.13)**	**-0.09 (-0.14, -0.04)**	0.00 (-0.04, 0.04)	0.01 (-0.03, 0.05)	0.01 (-0.03, 0.05)
SSB	**0.20 (0.17, 0.23)**	**0.22 (0.19, 0.25)**	**0.18 (0.15, 0.21)**	**0.08 (0.05, 0.11)**	**0.06 (0.03, 0.08)**	**0.06 (0.03, 0.08)**	**0.06 (0.03, 0.08)**
Positive exposure control							
Self-concept	**0.82 (0.81, 0.84)**	**0.80 (0.78, 0.81)**	**0.76 (0.74, 0.78)**	**0.72 (0.71, 0.74)**	**0.54 (0.52, 0.56)**	**0.54 (0.52, 0.57)**	**0.54 (0.52, 0.56)**
Anxiety symptoms							
Exposures of interest							
Vegetables and fruit	**-0.16 (-0.21, -0.12)**	**-0.14 (-0.18, -0.09)**	**-0.07 (-0.12, -0.03)**	-0.01 (-0.05, 0.04)	0.06 (0.02, 0.10)	0.07 (0.02, 0.11)	0.06 (0.02, 0.10)
SSB	**0.19 (0.17, 0.22)**	**0.21 (0.19, 0.24)**	**0.18 (0.16, 0.21)**	**0.11 (0.09, 0.14)**	**0.10 (0.07, 0.12)**	**0.10 (0.07, 0.12)**	**0.10 (0.07, 0.12)**
Positive exposure control							
Self-concept	**0.65 (0.63, 0.67)**	**0.61 (0.59, 0.62)**	**0.58 (0.56, 0.60)**	**0.56 (0.54, 0.58)**	**0.44 (0.42, 0.46)**	**0.44 (0.41, 0.46)**	**0.43 (0.41, 0.46)**
Psychological wellbeing							
Exposures of interest							
Vegetables and fruit	**0.53 (0.49, 0.58)**	**0.50 (0.45, 0.54)**	**0.43 (0.38, 0.47)**	**0.28 (0.24, 0.33)**	**0.12 (0.10, 0.15)**	**0.12 (0.09, 0.15)**	**0.12 (0.09, 0.15)**
SSB	**-0.13 (-0.16, -0.10)**	**-0.16 (-0.18, -0.13)**	**-0.12 (-0.14, -0.09)**	**-0.05 (-0.07, -0.02)**	**-0.01 (-0.03, 0.00)**	**-0.01 (-0.03, 0.00)**	**-0.02 (-0.03, 0.00)**
Positive exposure control							
Self-concept	**-0.87 (-0.89, -0.86)**	**-0.89 (-0.90, -0.87)**	**-0.88 (-0.90, -0.87)**	**-0.85 (-0.86, -0.83)**	**-0.49 (-0.50, -0.47)**	**-0.49 (-0.51, -0.48)**	**-0.49 (-0.50, -0.48)**

β: unstandardized beta-coefficients from linear mixed-effects models.

*Model 1 was adjusted for weekly spending money, age, sex; Model 2 – additionally adjusted for breakfast skipping, weight loss attempts; Model 3 – additionally adjusted for physical activity, screen time, sleep, smoking cigarettes and e-cigarettes, binge-drinking, cannabis use; Model 4 – additionally adjusted for supportive social relationships and happy family life; Model 5 additionally adjusted for self-perceived weight status; and Model 6 – additionally adjusted for race/ethnicity, geographic location, and academic achievement.

Appendices

Appendix J

Akaike's information criterion (AIC) in prospective associations between fruit and vegetables intake, SSB consumption, self-concept (i.e., positive exposure control) at baseline and depressive and anxiety symptoms, and psychological wellbeing at 1-year follow-up in COMPASS study.

	Unadjusted	**Model 1***	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Sensitivity analyses**	
							Model 6	**Model 7**
	AIC	**AIC**	**AIC**	**AIC**	**AIC**	**AIC**	**AIC**	**AIC**
Depressive symptoms								
Exposure of interest								
Vegetables and fruit	89033.33	82723.02	82514.66	82429.62	82374.38	82257.59	82232.99	82235.63
SSB	88998.32	82717.52	82494.20	82414.17	82365.84	82250.87	82226.61	82229.11
Positive exposure control								
Self-concept	85292.14	82279.60	82126.10	82080.63	82059.64	82043.49	82038.23	82043.52
Anxiety symptoms								
Exposure of interest								
Vegetables and fruit	86775.11	79992.63	79617.44	79560.04	79536.67	79493.09	79478.51	79483.63
SSB	86696.60	79988.90	79601.29	79549.23	79533.42	79491.56	79477.40	79482.53
Positive exposure control								
Self-concept	84091.43	79730.29	79397.40	79374.42	79371.28	79379.65	79376.55	79378.61
Psychological wellbeing								
Exposure of interest								
Vegetables and fruit	86158.54	79099.65	79022.09	78997.18	78941.47	78851.29	78834.58	78834.52
SSB	86454.86	79125.71	79035.03	79008.88	78944.83	78855.49	78838.12	78837.07
Positive exposure control								
Self-concept	81444.55	78736.30	78684.84	78676.45	78624.09	78580.06	78581.47	78584.23

β: unstandardized beta-coefficients from linear mixed-effects models; AIC: Akaike's information criterion.
*Model 1 adjusted for depressive and anxiety symptoms at baseline (as appropriate); Model 2 – additionally adjusted for weekly spending money, age, sex; Model 3 – additionally adjusted for breakfast skipping, weight loss attempts; Model 4 – additionally adjusted for physical activity, screen time, sleep, smoking

cigarettes and e-cigarettes, binge-drinking, cannabis use; Model 5 – additionally adjusted for so supportive social relationships and happy family life; Model 6 – additionally adjusted for self-perceived weight status; and Model 7 – additionally adjusted for race/ethnicity, geographic location, and math score.

Appendix K

Sex as the predictor of the initial level and rate of change in VF and SSB consumption using multilevel linear growth curve models.

Dependent variable	**Coefficient**	**Standard error**	**p-value**
Vegetables & fruit consumption			
Fixed effect			
Intercept	**3.169**	**0.034**	**<0.001**
Age	**-0.215**	**0.036**	**<0.001**
Male	0.052	0.051	0.305
Male*age	**0.057**	**0.024**	**0.015**
Random effects			
Variance (intercept)	2.070	0.065	NP
Variance (time)	0.040	0.017	NP
Covariance (intercept, time)	-0.065	0.025	NP
Residual variance	1.854	0.030	NP
SSB consumption			
Fixed effect			
Intercept	**3.615**	**0.055**	**<0.001**
Age	**0.154**	**0.062**	**0.013**
Male	**0.243**	**0.084**	**0.004**
Male*age	0.045	0.040	0.272
Random effects			
Variance (intercept)	5.738	0.184	NP
Variance (time)	0.287	0.051	NP
Covariance (intercept, time)	0.198	0.074	NP
Residual variance	4.871	0.083	NP

Appendices

Appendix L

Associations of individual adherence to 12 lifestyle recommendations with the CESD-R-10 and GAD-7 scores at baseline.

	Univariate	**Multivariable***			
		Model 1	**Model 2**		
	Total	**Total**	**Total**	**Females**	**Males**
	β (95% CI)	**β (95% CI)**	**β (95% CI)**	**β (95% CI)**	**β (95% CI)**
Adherence to individual recommendations for:			***Depressive symptoms***		
Vegetables and fruit	0.02 (-0.35, 0.39)	-0.07 (-0.42, 0.28)	0.27 (-0.07, 0.62)	0.20 (-0.27, 0.67)	0.28 (-0.24, 0.80)
Grain products	-0.09 (-0.44, 0.25)	0.24 (-0.09, 0.57)	0.50 (0.17, 0.82)	0.38 (-0.13, 0.90)	**0.54 (0.14, 0.94)**
Milk and alternatives	**-0.88 (-1.03, -0.73)**	**-0.25 (-0.40, -0.10)**	-0.09 (-0.23, 0.05)	-0.07 (-0.29, 0.15)	-0.12 (-0.30, 0.06)
Meat and alternatives	**-0.40 (-0.54, -0.25)**	**-0.85 (-0.99, -0.71)**	**-0.73 (-0.87, -0.59)**	**-1.11 (-1.31, -0.90)**	**-0.24 (-0.42, -0.06)**
SSB	**-0.90 (-1.06, -0.74)**	**-0.93 (-1.08, -0.77)**	**-0.51 (-0.66, -0.36)**	**-0.61 (-0.83, -0.40)**	**-0.39 (-0.59. -0.19)**
MVPA	**-0.49 (-0.64, -0.34)**	-0.02 (-0.16, 0.13)	-0.02 (-0.16, 0.12)	**0.21 (0.00, 0.43)**	**-0.25 (-0.43, -0.07)**
Screen time	**-1.83 (-2.16, -1.49)**	**-1.73 (-2.04, -1.41)**	**-1.19 (-1.50, -0.88)**	**-1.26 (-1.68, -0.84)**	**-0.86 (-1.32, -0.41)**
Sleep	**-2.35 (-2.49, -2.20)**	**-1.91 (-2.05, -1.76)**	**-1.70 (-1.84, -1.56)**	**-1.85 (-2.05, -1.64)**	**-1.54 (-1.72, -1.36)**
No tobacco smoking	**-3.06 (-3.34, -2.77)**	**-2.94 (-3.22, -2.67)**	**-1.47 (-1.78, -1.16)**	**-1.97 (-2.45, -1.49)**	**-1.18 (01.56, -0.79)**
No vaping	**-1.69 (-1.88, -1.49)**	**-1.76 (-1.95, -1.58)**	**-0.48 (-0.70, -0.27)**	**-0.83 (-1.15, -0.50)**	-0.27 (-0.54, 0.01)
No cannabis use	**-2.65 (-2.86, -2.44)**	**-2.46 (-2.67, -2.26)**	**-1.24 (-1.48, -1.00)**	**-1.56 (-1.92, -1.20)**	**-0.85 (-1.16, -0.53)**
No binge drinking	**-1.79 (-1.96, -1.62)**	**-1.56 (-1.73, -1.39)**	**-0.43 (-0.62, -0.24)**	**-0.57 (-0.85, -0.29)**	-0.08 (-0.33, 0.16)
Adherence to individual recommendations for:			***Anxiety symptoms***		
Vegetables and fruit	**0.43 (0.09, 0.77)**	0.25 (-0.07, 0.58)	**0.45 (0.13, 0.77)**	**0.47 (0.04, 0.90)**	0.29 (-0.20, 0.78)
Grain products	0.09 (-0.23, 0.41)	**0.44 (0.14, 0.74)**	**0.56 (0.25, 0.86)**	0.44 (-0.04, 0.91)	**0.62 (0.25, 1.00)**
Milk and alternatives	**-0.77 (-0.91, -0.63)**	-0.11 (-0.24, 0.02)	-0.03 (-0.16, 0.11)	0.06 (-0.14, 0.27)	-0.11 (-0.28, 0.06)
Meat and alternatives	-0.03 (-0.16, 0.11)	**-0.58 (-0.71, -0.45)**	**-0.53 (-0.66, -0.40)**	**-0.82 (-1.09, -0.63)**	-0.12 (-0.29, 0.05)
SSB	**-0.79 (-0.94, -0.65)**	**-0.85 (-0.99, -0.71)**	**-0.55 (-0.69, -0.42)**	**-0.62 (-0.82, -0.42)**	**-0.46 (-0.65, -0.28)**
MVPA	**-0.42 (-0.56, -0.28)**	0.09 (-0.04, 0.23)	0.07 (-0.06, 0.20)	**0.28 (0.09, 0.48)**	-0.15 (-0.32. 0.02)
Screen time	**-1.06 (-1.37, -0.76)**	**-1.08 (-1.37, -0.79)**	**-0.66 (-0.94, -0.37)**	**-0.66 (-1.05, -0.28)**	**-0.52 (-0.95, -0.09)**
Sleep	**-1.76 (-1.89, -1.62)**	**-1.36 (-1.49, -1.23)**	**-1.20 (-1.33, -1.08)**	**-1.40 (-1.59, -1.22)**	**-0.97 (-1.14, -0.80)**
No tobacco smoking	**-2.24 (-2.50, -1.97)**	**-2.18 (-2.43, -1.93)**	**-1.06 (-1.34, -0.77)**	**-1.46 (-1.90, -1.02)**	**-0.80 (-1.16, -0.44)**

No vaping	**-1.23 (-1.41, -1.05)**	**-1.33 (-1.50, -1.16)**	**-0.34 (-0.54, -0.14)**	**-0.65 (-0.95, -0.35)**	-0.14 (-0.40, 0.11)
No cannabis use	**-2.00 (-2.20, -1.81)**	**-1.81 (-2.00, -1.63)**	**-0.86 (-1.09, -0.64)**	**-1.01 (-1.34, -0.68)**	**-0.69 (-0.99, -0.40)**
No binge drinking	**-1.50 (-1.65, -1.34)**	**-1.24 (-1.39, -1.09)**	**-0.41 (-0.58, -0.23)**	**-0.48 (-0.74, -0.22)**	-0.19 (-0.42, 0.04)

β: unstandardized regression coefficients; 95% CI: 95% confidence interval; SSB: sugar-sweetened beverages; MVPA: moderate-to-vigorous physical activity.
*In linear mixed-effect models, Model 1 was adjusted for age, ethnicity, weight status, weight perception, weight loss attempts, school- area median household income, and school area urban class. Model 2 was mutually adjusted for other lifestyle behaviours. Not meeting recommendations was the reference category in all analyses presented in Table S1. CIs that do not include the null value are bolded.

Appendix M

Associations of overall adherence to 12 lifestyle recommendations with CESD-R-10 and GAD-7 scores at baseline.

	Univariate	**Multivariable***		
	Total	**Total**	**Females**	**Males**
	β (95% CI)	**β (95% CI)**	**β (95% CI)**	**β (95% CI)**
*Lifestyle based on overall adherence***		***Depressive symptoms***		
Unfavourable	**-2.32 (-2.55, -2.09)**	**-2.11 (-2.33, -1.88)**	**-2.69 (-3.02, -2.37)**	**-1.37 (-1.66, -1.08)**
Intermediate	**-4.03 (-4.27, -3.78)**	**-3.56 (-3.80, -3.32)**	**-4.44 (-4.79, -4.08)**	**-2.49 (-2.81, -2.17)**
Favourable	**-4.95 (-5.79, -4.11)**	**-3.99 (-4.81, -3.19)**	**-5.31 (-6.62, -4.01)**	**-2.76 (-3.73, -1.79)**
Per recommendation met:	-0.76 (-0.80, 0.72)	**-0.67 (-0.71, -0.63)**	**-0.85 (-0.91, -0.79)**	**-0.47 (-0.52, -0.42)**
Lifestyle based on overall adherence		***Anxiety symptoms***		
Unfavourable	**-1.87 (-2.09, -1.66)**	**-1.64 (-1.84, -1.43)**	**-2.04 (-2.34, -1.75)**	**-1.12 (-1.39, -0.85)**
Intermediate	**-3.09 (-3.32, -2.86)**	**-2.66 (-2.88, -2.43)**	**-3.26 (-3.59, -2.94)**	**-1.89 (-2.19, -1.60)**
Favourable	**-3.86 (-4.64, -3.08)**	**-2.92 (-3.67, -2.18)**	**-4.10 (-5.28, -2.91)**	**-1.87 (-2.77, -0.97)**
Per recommendation met:	**-0.56 (-0.60, -0.53)**	**-0.48 (-0.52, -0.44)**	**-0.60 (-0.66, -0.55)**	**-0.33 (-0.38, -0.29)**

β: unstandardized regression coefficients; 95% CI: 95% confidence interval; SSB: sugar-sweetened beverages; MVPA: moderate-to-vigorous physical activity.
*Multivariable linear mixed-effects models were adjusted for age, ethnicity, weight status, weight perception, weight loss attempts, school- area median household income, and school area urban class. Meeting 3 or less recommendations was the reference category in analyses where lifestyle based on overall adherence was the independent variable. CIs that do not include the null value are bolded.
**Those meeting 3 or less recommendations were classified as having very unfavourable, 4-6 – unfavourable, 7-9 – intermediate, and 10-12 – favourable lifestyles.

Appendix N

Post-hoc analyses for the diet-mental health association that account for the co-occurrence of depressive and anxiety symptoms.

	Unadjusted	**Final models***	**Co-adjusted models‡**
	β (95% CI)	**β (95% CI)**	**β (95% CI)**
Depressive symptoms			
Exposure of interest			
VF	**-0.24 (-0.29, -0.19)**	0.03 (-0.02, 0.07)	0.02 (-0.03, 0.06)
SSB	**0.17 (0.14, 0.20)**	**0.04 (0.01, 0.06)**	**0.03 (0.00, 0.05)**
Positive exposure control			
Self-concept	**0.68 (0.66, 0.70)**	**0.19 (0.17, 0.22)**	**0.18 (0.15, 0.20)**
Anxiety symptoms			
Exposure of interest			
VF	**-0.12 (-0.17, -0.07)**	0.03 (-0.01, 0.07)	0.04 (-0.00, 0.08)
SSB	**0.15 (0.12, 0.17)**	**0.02 (0.00, 0.05)**	**0.03 (0.00, 0.05)**
Positive exposure control			
Self-concept	**0.53 (0.52, 0.55)**	**0.12 (0.10, 0.15)**	**0.09 (0.07, 0.11)**

β: unstandardized regression coefficients; 95% CI: 95% confidence interval; SSB: sugar-sweetened beverages; VF: vegetables and fruit.
*Final models from Chapter 3.
‡Co-adjusted models: final models for depressive symptoms were additionally adjusted for baseline anxiety symptoms (in addition to depressive symptoms at baseline, weekly spending money, age, sex, breakfast skipping, weight loss attempts, physical activity, screen time, sleep, smoking cigarettes and e-cigarettes, binge-drinking, cannabis use, and supportive social relationships and happy family life), and vice versa.