Depression and Links to Diet Quality

by

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Abstract

Background: Depression is a common condition. One in five Canadians will experience a mental health condition such as depression, anxiety or bipolar disorder in his/her lifetime. It has been claimed that diet quality is associated with depression. We sought to investigate the evidence for this claim in the Canadian population.

Objectives: The aim of this study was to: (a) establish how fruit and vegetable consumption patterns by Canadians in 2016, based on the CCHS Annual Component 2015-16 relate to the state of self-reported mental health of individuals. Particular interest is dedicated to: (a) estimating whether fruit and vegetable intake is related to self-reported mental health (depression); (b) determining whether and to what extent there is an association between fruit and vegetable intake and life satisfaction (proxy of subjective well-being); (c) estimating whether there is an association between fruit and vegetable intake, self-reported mental health, and life satisfaction/well-being and whether this relationship is uni-directional or bi-directional.

Design: The present study has a cross-sectional design using data from the Statistics Canada Canadian Community Health Survey – Annual Component 2015-16. Our final sample size included 25,063 participants.

Methods: Frequency of fruit and vegetable intake was cross-tabulated with demographic and health variables to describe differences between certain age groups, sexes, and comparisons between education and income level, household food security status, physical activity levels, BMI, perceived general health, perceived mental health, satisfaction with life, sleeping, smoking and drinking behaviour of the respondents. Pearson's correlation coefficients were used to test

the strength of the association between dependent and independent variables. To test further test the relationship between diet and mental health and diet and satisfaction with life, linear and maximum likelihood regressions were run. In total, five regression models were then evaluated.

Results: The data revealed that fruit and vegetable consumption in the Canadian population in 2016 was very low (mean=3.81). The pattern of association between fruit and vegetable intake and depression indicated that this relationship is bi-directional. Examination of the other socio-demographic and health characteristics revealed that all of them were significant predictors of depression. Drinking was found not to be associated with satisfaction with life or fruit and vegetable consumption.

Conclusions: The data from this study suggested that dietary patterns, as represented by fruit and vegetable self-reported intake, of Canadians remain a public health concern. That it is linked to depression and life satisfaction suggests a need to focus on improving dietary quality to reduce depression and increase life satisfaction. Health promotion techniques/effective nutrition education programmes can be better targeted towards certain groups of individuals, such as people who suffer from depression, who might benefit based on the results of this study.

Introduction

Depressive disorders are now the leading cause of disability in middle to high income countries (WHO, 2004). There are more than 6.7 million people in Canada currently living with a mental health condition (Mental Health Commission of Canada, 2013). It is one of the most commonly diagnosed psychiatric illnesses (Martínez-González & Sánchez-Villegas, 2016), making mental health and well-being a critical modern public health issue. Based on data from 2010, the global direct and indirect economic costs of mental disorders were estimated at US$2.5 trillion. Both direct and indirect costs of mental disorders are expected to double by 2030 (Trautmann et al., 2016). In Canada, mental health issues accounted for more than $6 billion in lost productivity in 2011 (Mental Health Commission of Canada, 2013). If unaddressed, the impact of mental health conditions on lost productivity will cost Canadian businesses $198 billion over the next 30 years (Mental Health Commission of Canada, 2013).

An extensive body of scientific evidence suggests that poor dietary intake is a significant contributor to an array of adverse health outcomes, such as cardio-vascular disease, diabetes, and certain forms of cancer (Bonow, 2002, Lanier et al., 2015). However, growing evidence also suggests that nutrition affects mental health as well as physical health. It is known that genetic (Wallace et al., 2002) and biological factors underlie the onset of depression, but there is also evidence that diet has the potential to regulate several of these factors (e.g. Jacka & Berk, 2007).

Support that nutrition can regulate mental health comes from epidemiological studies which find that a healthy dietary pattern including fruits, vegetables, fish, olive oil, nuts and legumes is protective against depression (Kyrozis et al., 2009, Lang et al., 2015). For example, a longitudinal study from United Kingdom examined adherence to a healthy diet using the

Alternative Healthy Eating Index (AHEI) and recurrent depressive symptoms were defined as having a Center for Epidemiologic Studies Depression Scale score ≥16 or self-reported use of antidepressants (Abkaraly et al., 2013). In this study, the AHEI score was inversely associated with recurrent depressive symptoms in a dose-response fashion in women and there was a suggestion that poor diet is a risk factor for future depression in women. Among AHEI components, vegetable, fruit, trans fat, and the ratio of polyunsaturated fat to saturated fat components were associated with recurrent depressive symptoms in women.

Conversely, a dietary pattern that comprises a high consumption of processed foods and sugary products may increase the risk of depression (Sanhueza et al., 2013). The diet and mental health relationship is therefore assumed to be bi-directional – depression may lead to unhealthy dietary patterns (e.g. "emotional eating"), including lower intake of fruits and vegetables (Konttinen et al., 2010).

Influence of food on well-being and satisfaction with life in general, are studied less frequently. Well-being refers to how people experience and evaluate their lives. Nonetheless, some associations between health and well-being in a food-related context have been previously described in literature (Ares et al., 2015, Mujcic & Oswald, 2016, Walsh & Kiviniemi, 2014). Using a questionnaire comprising five open-ended questions about foods and well-being, Ares et al. found that fruits, vegetables, and fish were the main foods recognized as positive for well-being, whereas foods high in fat, salt and sugar, meat products, junk food and fried food were perceived as harmful (Ares et al., 2015). A longitudinal study from Australia examined food diaries of randomly assigned individuals and found that increased fruit and vegetable

consumption was predictive of increased happiness, life satisfaction, and well-being (Mujcic & Oswald, 2016).

Overall diet quality plays a protective role in the onset of chronic diseases as well as mental health disorders. Maintaining healthy body weight, improving dietary patterns and, in turn, improving nutritional status, is viewed as a key way to improve public health. However, current knowledge of food patterns and its association with mental health disorders in Canadians is rather limited. There is a need to assess whether diet quality can make a difference in their association with a lower risk of depression. An understanding of the comorbidity of depression and other mental health disorders with obesity may provide a clearer understanding of the benefits of improved diet as a target for preventive strategies. Poor diet quality may be a modifiable risk factor for depression and the potential for dietary intervention could be used as a treatment and preventive approach at the clinical and population level (Opie et al., 2015).

Research Objectives

The purpose of the present study is to examine some of the relationships between depression and dietary quality. If depression is linked to dietary quality then improving diet might reduce some aspects of depression in some individuals. The relationship to be studied will be addressed using data from the Canadian Community Health Survey, data that is collected regularly by Statistics Canada. From that data set, depression can be assessed using the Patient Health Questionnaire (PHQ-9) scale and diet quality measures are limited to fruit and vegetable consumption. However many other confounding variables are included in the data set such as physical activity smoking, sleeping, food security and demographic variables. In this study the focus is on: (a) estimating whether fruit and vegetable intake is related to self-reported mental health

(depression); (b) determining whether and to what extent there is an association between fruit and vegetable intake and life satisfaction (proxy of subjective well-being); (c) estimating whether there is an association between fruit and vegetable intake, self-reported mental health, and life satisfaction/well-being. Since there is the possibility of reverse causality and these relationships may be bi-directional, key variables will be tested both as explanatory variables and dependent variables in order to establish whether there is a uni-directional or bi-directional relationship. Descriptive statistics and regression will be used to test relationships. A literature review will be used to identify variables and relationships that can be tested with this dataset.

Literature review

Diet quality and fruit and vegetable consumption

Dietary patterns and overall diet quality rather than single nutrients have been identified as important predictors of depression. Over the years, several diet quality indexes have been developed (e.g. Healthy Eating Index (HEI), a Mediterranean Diet Quality Index, the Diet Quality Index Revised (DQI-R) among others). The underlying component of all the indexes and diets that are beneficial for mental health is the inclusion and promotion of regular fruit and vegetable consumption. In recent years the use of single measures of diet quality is becoming widely accepted. For instance, a Canadian study conducted a comparison of the diet quality index scores with other indicators of diet quality and found that simple indicators, such as frequency of fruit and vegetable consumption, can measure diet quality well (Garriguet, 2009). Additionally, a study examining diet quality and mental health in adolescents demonstrated that fruit and vegetable intake is a primary component of a healthy diet and could be used as a marker of diet quality (Jacka et al., 2011).

Fruits and vegetables are nutrient dense foods, high in fibre and rich in essential nutrients such as folate, vitamin B6 and B12, magnesium and zinc. Dietary inadequacy of such nutrients has been implicated in the development of depression (Jacka et al., 2009, Lang et al., 2015, Jacka et al., 2011). On the other hand, there is evidence that people with diets high in fruit and vegetables have lower risk of depression (Głąbska et al., 2020). Besides, research also suggests that a dose-response relationship exists, such that every increased intake of fruits and vegetables is associated with a reduced risk of depression (Saghafian et al., 2018).

Multiple factors influence food choice and thus diet quality on a number of levels; for example, budget, health motivations, knowledge in nutrition and education in general among others. Material factors appear to be studied most often with regard to fruit and vegetable intake. A series of reviews suggested a relationship between socio-demographic factors and food choice (Kamphuis et al., 2015, Kamphuis et al., 2006, Markussen 2016), indicating that higher socioeconomic groups valued health more than did lower socioeconomic groups. People living in households with a higher income had a greater fruit and vegetable consumption (Wandel, 2005). Lower socioeconomic groups are more likely to consume diets high in fat and low in micronutrient density and to have lower intakes of fruit and vegetables (Giskes et al., 2004, Giskes et al., 2009, Inglis et al., 2008).

Many other socio-demographic and lifestyle factors have effect on food choices. Markussen and colleagues noted that adherence to a healthier lifestyle was related to older age, higher education, higher body mass index (BMI), more physical activity and being a non-smoker (Markussen et al., 2016). The positive association between healthy dietary patterns and higher BMI may indicate that overweight people adopt a healthy diet to lose weight.

Evidence suggests that women are more likely to make healthier choices (Arganini et al., 2012) and have higher frequency of fruit and vegetable intake (Riediger et al., 2007, Wardle et al., 2004). Wardle at al. examined gender differences in food choices and found that women in 23 different countries are more likely than men to report avoiding high-fat foods, eating fruit and fibre, and limiting salt. They are also more likely to be dieting and attaching greater importance to healthy eating. Gender differences in food choices therefore appear to be partly attributable to

women's greater weight control involvement and partly to their attitudes and stronger beliefs in healthy eating (Wardle et al., 2004).

A significant body of research demonstrates a relationship between educational attainment and diet. Barker indicates that women who leave school with few or no educational qualifications are less likely to have diets that meet current recommendations than women who attain more qualifications at school (Barker et al., 2008). Education level was the most important social variable in explaining differences in vegetable and fat intake in a random sample of Danish men and women (Groth et al., 2001), and having no qualifications was a significant predictor of low healthy-eating scores in 7434 men and women in the Scottish Health Survey (Shelton et al., 2005).

Mental health

Mood and anxiety disorders frequently coexist with other chronic diseases or conditions. For example, a population-based study done by Boing et al. have found that the prevalence of depression is much higher among people with a higher burden of chronic diseases (Boing at al., 2012). Similarly, smoking (Pasco et al., 2008) and alcohol consumption (Haynes et al., 2005) have been implicated as independent risk factors for depression.

Social epidemiology has established that food insecurity frequently coexists with mental illness. For example, there is evidence that food insecure individuals are more likely than food secure individuals to experience elevated anxiety, depression, and other symptoms of common mental disorders (Weaver, 2009, Willows et al., 2011). A recent study based on administrative health care data that was linked to four cycles of CCHS, found that household food insecurity status is a robust predictor of mental health service utilization among working-age adults in Ontario

(Tarasuk et al., 2018). A systematic review that assessed both qualitative and quantitative studies has illustrated how the experience of food insecurity affects the wide range of physical, mental, and emotional symptoms (Weaver, 2009).

The financial stress of food insecurity has been shown to precipitate mental health problems (Tarasuk et al., 2018). But food insecurity is also characterized by systematically lower intakes of number of nutrients in different food groups, including lower fruit and vegetable intake (Tarasuk, 2001) and this nutrient inadequacy may influence cognitive function (Gao et al., 2009). Irrespective of which condition came first, food insecurity and mental health illness are the two problems that appear to frequently coexist.

Another factor that affects mental health is chronic sleep deprivation. Although disturbed sleep (insomnia and hypersomnia) is associated with psychiatric disorders and is traditionally considered to be a symptom of depression (Nutt et al., 2008), research also suggests that the relationship between sleep changes and mood disorders may have strong bi-directional relationship. Lack of sleep in nondepressed subjects is a risk factor for later development of depression that is potentially attributable to the neurological changes that occur in the brain (Al-Abri, 2015, Nutt et al., 2008).

Additionally, there is epidemiologic data on the relationship between inadequate sleep duration and obesity related behaviours, such as lower physical activity and lower fruit and vegetable consumption (Stamatakis & Brownson, 2008).

Evidence suggests that depressive symptoms are associated with inadequate physical activity (Chai et al., 2010) and at the same time there are studies that offered plausible evidence that physical exercise reduces depression (Josefsson et al., 2013). There is also indication that simultaneous presence of high fruit and vegetable intake as well as leisure time physical activity reduce the likelihood of developing depressive symptoms (Chi et al., 2015) and have protective effects on clinically relevant levels of depressive symptoms (Ribeiro et al., 2017). In the study done by Ribeiro and the colleagues fruit and vegetable intake as well as physical activity levels were self-reported. CES-D (Center for Epidemiological Studies Depression Scale), an 11-item scale, was used to identify those who met the criteria for clinically relevant levels of depressive symptoms.

Associations between physical activity, body mass index (BMI) and fruit and vegetable consumption have been consistently demonstrated in numerous studies (Lahti-Koski et al., 2002, Lowry et al., 2000). A study from Finland examined the consistency of these associations over time, and found that in men and women, perceived general health, physical activity, and daily vegetable consumption were inversely associated with obesity (Lahti-Koski et al., 2002). Despite the fact that the cross-sectional design undertaken by Lahti-Koski et al. study does not allow to draw causal conclusions, the repeated surveys carried out at the same time of year in 1982, 1987, 1992, and 1997 with a large number of participants and a high participation rate do provide unique information on food choices, physical activity and obesity over time.

Depression and anxiety are also widely acknowledged as having an association with features of the metabolic syndrome, which is a common metabolic disorder that results from the increasing prevalence of obesity and increases the risk for type 2 diabetes and cardiovascular disease (Eckel

et al., 2005). Multiple studies and meta-analyses demonstrated that depressive symptoms and obesity are both common conditions with significant adverse effects on health that may be greater when the two conditions occur together. Many of these studies indicate that mental health disorders are frequently reported among overweight and obese individuals and this relationship may be bi-directional, such that obese persons were at increased risk of developing depression over time and depressed individuals were at increased risk of becoming obese (Pan et al., 2012, Murabito et al., 2013).

A recent study identified biologically plausible pathways between dietary patterns, adiposity, inflammation, and depression, linking diet and BMI to inflammation and, in turn, mental health disorders in adolescents (Oddy et al, 2018). It is clear that obesity and depressive disorders are common comorbidities and have discrete, yet overlapping, pathoetiology. As dietary patterns tend to be associated with these other health-related behaviours, it is difficult to disentangle the relations between fruit and vegetable intake, other lifestyle factors and mental health.

Subjective well-being

Mental health assessment wouldn't be complete without evaluating the presence of positive mental health. In recent years, it has been increasingly recognized that the absence of mental disorder is not considered enough for people to have good mental health (WHO, 2001). In this view, recognizing a more holistic mental health concept, both the absence of mental health disorders as well as subjective well-being are required for complete mental health assessment.

World Health Organization describes subjective well-being as "good mental states, including all of the various evaluations, positive and negative, that people make of their lives, and the affective reactions of people to their experiences" (OECD, 2013).

In general, there is a consensus among academics that the concept of subjective well-being involves two broad elements: people's cognitive and affective evaluations of their lives (e.g. Veenhoven, 1997, Kashdan, 2004). Where 'cognitive appraisal' refers to overall life satisfaction and a person's satisfaction with specific domains (e.g. family life, career, and so forth). 'Affective appraisal' describes emotional experience of positive states, like joy and hope, and the negative ones, like anger, disappointment, etc. (Kashdan, 2004). Therefore, subjective well-being encompasses momentary assessments (fleeting day-to-day experiences) of affect as well as overall life evaluations. And these two concepts are central to the quality of life as individuals.

Although inherent factors, like personality characteristics, play a fundamental role in subjective well-being, individual, contextual and situational factors are important too. In particular, a consistent finding is that better health is associated with higher subjective well-being (Van Hoorn, 2007).

There are different measures to evaluate well-being. Most are self-report questionnaires designed to capture judgments of specific aspects of life, such as relationships, community, health, or occupation, as well as global life evaluations. For example, Diener and colleagues developed a Satisfaction With Life Scale (SWLS), which is a compact instrument questionnaire for measuring overall life satisfaction (Diener et al., 1985). It looks specifically at the life satisfaction construct and doesn't include items for affect. With good internal consistency and temporal reliability, it consists of five statements where participants can indicate a level of

agreement on a 7-point scale, where one = “Strongly Disagree,” and seven = “Strongly Agree,” a higher score indicates higher life satisfaction.

The Oxford Happiness Questionnaire (OHQ) was developed in 2002 by researchers Hills and Argyle as an improvement on the Oxford Happiness Inventory, which was being used at the time to measure subjective well-being (Hills & Argyle, 2002). Participants use a 1-6 scale to report how much they agree with 29 items, where 1 indicates the strongest disagreement possible and six the strongest agreement. OECD recommends using the following question “Overall, how satisfied are you with life as a whole these days?” (OECD, 2013). In sum, subjective well-being measures are meaningful in the sense that they are able to provide valid and reliable information on how well people (and societies) as a whole are doing (Van Hoorn, 2007).

Study Setting and Research Methods

Data Source

Data was obtained from the Statistics Canada Canadian Community Health Survey (CCHS), Annual Component 2015-16[1]. CCHS is a cross-sectional survey that collects information related to health status, health care utilization and health determinants for the Canadian population. Over a two year period, data are based on interviews with approximately 130,000 respondents aged 12 or older, residing in households in all provinces and territories, excluding individuals living on reserves and other Aboriginal settlements in the provinces; full-time members of the Canadian Forces; the institutionalized population, children aged 12-17 that are living in foster care, and persons living in the Quebec health regions of Région du Nunavik and Région des Terres-Cries-de-la-Baie-James. The CCHS is representative of 98% of the Canadian population.

Data collection for this annual component started in January 2016 and was completed in December 2016. Data was collected directly from survey respondents on a voluntary basis and the response rate was 59.5%. Details are available elsewhere (Statistics Canada, 2016).

Sampling Procedure

From 2015 onwards, the CCHS sample is selected using two different frames: an Area frame and the Canadian Child Tax Benefit frame. Using the Area frame, a sample of dwellings is selected to target the population aged 18 and over. During collection, all members of the dwelling are listed and a person aged 18 years or over is automatically selected using various selection probabilities based on age and household composition. The Canadian Child Tax Benefit frame is

[1] The data is downloadable from Statistics Canada website https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=3226.

used to sample persons aged 12 to 17 years. One child is then pre-selected to complete the survey.

For the purpose of this study, the analysis was restricted to the population aged 20 and older, because they are more likely than younger people to make their own food choices.

Data Collection

Data were collected using computer assisted personal and telephone interview software. This was done in order to customise each application's functionality to the type of interview being conducted. Each application consisted of an entry component, a health content, and an exit component. Respondents are initially offered to complete the interview in either English or French. When necessary, interviewers with a wide range of language competencies were recruited to remove language as a barrier. Health Statistics Division has linked the 2016 CCHS survey data to existing tax files to collect income information.

Outcome of interest: mental health (depression)

The primary outcome of interest was whether or not the respondent was experiencing depressive symptoms over the 2 weeks preceding the survey interview. It was assessed using the Depression (DEP) questions in the CCHS 2015-16. The questions of this module are based on a validated instrument to measure self-reported depression - The Patient Health Questionnaire depression scale (PHQ-9).

PHQ-9 was developed by Spitzer et al. in 1999 and it is a 9-item measure of depression severity with a user-friendly response format, short administration time and easy scoring (Spritzer et al.,

1999). This scale was developed for dual-purpose as the same nine items can establish provisional depressive disorder diagnoses as well as grade depressive symptom severity.

Unlike many other depression rating scales, the PHQ-9 items align with those of the American Psychiatric Association Diagnostic and Statistical Manual of Mental Disorders, 5th edition (DSM-V, 2013).

Major depression is diagnosed if five or more of the nine depressive symptom criteria have been present at least "more than half the days" in the past 2 weeks, and one of the symptoms is depressed mood or anhedonia. One of the nine symptom criteria ("thoughts that you would be better off dead or of hurting yourself in some way") counts if present at all, regardless of duration.

As a severity measure, the PHQ-9 score ranges from 0 to 27, because each of the 9 items can be scored from 0 ("not at all") to 3 ("nearly every day"). 5, 10, 15, and 20 cut-points represent the thresholds for mild, moderate, moderately severe, and severe depression, respectively (Kroeke et al., 2001). Kroenke et al. recommend a PHQ-9 score of 10 or greater if a single screening cut-point has to be chosen. However, they also add that scores less than 10 seldom occur in individuals with major depression whereas scores of 15 or greater usually signify the presence of major depression and requires treatment (Kroenke et al., 2001).

For purposes of this study, the depression scale in its raw form was used. However, for additional descriptive analyses of the data the PHQ-9 scores were dichotomized using a cut-point of 15 points or more to define 'major depressive disorder'; 10 points or more to identify 'moderate depression' and 5 points or more for 'mild depression'.

In the context of mental health an additional outcome, potentially broader, investigated is self-reported subjective well-being. Elements of subjective well-being and mental health problems are seen as independent but correlated concepts (Lukat et al., 2016). Since they can be present at the same time, for more comprehensive research, these two concepts should be studied together. Life satisfaction is a proxy for subjective well-being as its' individual item scores of life satisfaction contain information on the respondents' global evaluation of their lives; it is a subjective evaluation and is made by individuals based on their own criteria or standards. Measures of life satisfaction, including single question measures of satisfaction with life, are well validated in the literature and have been incorporated into a number of national monitoring systems, including in Canada (Bonikowska et al., 2013). Organization for Economic Cooperation and Development also proposed that national statistical offices use measures of subjective well-being—including life satisfaction—to assess well-being (OECD, 2013).

Satisfaction with life as a whole was measured on 11-point scale with the following question: "Using a scale of 0 to 10, where 0 means "Very dissatisfied" and 10 means "Very satisfied", how do you feel about your life as a whole right now?". For regression analysis raw data was used, for additional analysis answers were grouped from 0 to 3 to identify those who are 'very dissatisfied or satisfied with life', from 4 to 7 for those who are 'neither satisfied, nor dissatisfied, and from 8 to 10 for people who are 'satisfied or very satisfied with life'.

Self-perceived mental health was measured with the question "In general, would you say your mental health is …?" Answers were grouped on a five-item scale from poor to excellent. Self-perceived health was measured with the question "In general, would you say your health is..?". Answers were grouped on a five-item scale from poor to excellent.

To measure overall health status, the participants were asked “In general, would you say your l health is …?” Answers were grouped on a five-item scale from poor to excellent. Self-perceived health was measured with the question “In general, would you say your health is..?”. Answers were grouped on a five-item scale from poor to excellent.

Perceived health and perceived mental health are indicators of overall health status, mental and social well-being. These two values can reflect aspects of health that are not captured in other measures, such as: disease severity, aspects of positive health status, physiological and psychological reserves and social and mental function. Perceived health in general can also act as a proxy for chronic conditions and comorbidities as it refers to the perception of a person’s health in general and physical well-being. At the same time, these two measures were found to have collinearity problems with other indicators, particularly satisfaction with life and depression, and therefore were excluded from the main analysis.

Exposure of interest: fruit and vegetable intake

CCHS includes six questions on frequency of fruit and vegetable consumption. The frequency was self-reported and determined by the mean number of times per day that respondents reported consuming fruits and vegetables, rather than the actual quantity consumed.

The fruit and vegetable module included the following questions: “In the last month, how many times per day, per week or per month did you drink 100% pure fruit juices, such as pure orange juice, apple juice or pure juice blends?” Subsequent questions included: “In the last month, not counting juice, how many times did you eat fruit?” “How many times did you eat dark green vegetables such as broccoli, green beans, peas and green peppers or dark leafy greens including romaine or spinach?”; “How many times did you eat orange-coloured vegetables such as carrots,

orange bell pepper, sweet potatoes, pumpkin or squash?"; "How many times did you eat potatoes that are not deep fried?"; "How many times did you eat other vegetables?".

Evidence on whether consumption of 100% fruit juice is a healthy dietary choice or has adverse health effects remains controversial. Many studies conclude that 100% fruit juice is not related to adiposity when consumed in *appropriate amounts* for age and energy needs (e.g. Hyson, 2015). However, there are reports that argue fruit juice consumption is comparable with consuming sugar-sweetened beverages that contribute to overweight and obesity (e.g. Gill & Sattar, 2014). The argument is that fruit juices are high in sugar and the body registers liquid sugar and solid sugar calories differently, and that liquid sugar calories lead to greater ad libitum energy intake than do solid sugar calories. Consequently, since there are many unanswered question related to pure fruit juice and health in humans and present evidence is inconclusive, consumption of fruit juice was not included in the assessment of fruit and vegetable intake.

Total fruit and vegetable intake was assessed by combining the responses to questions regarding consumption frequency of fruits (not counting juice), green salad, carrots and other vegetables. This provides a score representing how many servings of fruits and vegetables an individual consumed on a daily basis, this data was used to run linear regression analysis. For basic cross-tabulations the score was divided into quartiles based on the recommendations from Canada's Food Guide at the time (Katamay et al., 2007). Released in 2007, Eating Well with Canada's Food Guide is a dietary guidance that defines and promotes healthy eating among Canadians. It provides advice on the quality and amount of food for men and women, teens and children. Regarding fruits and vegetables, Canada's Food Guide recommends 7 to 8 servings per day of fruits and vegetables for females and 8 to 10 servings per day for males in the age group between

19 to 50. Ages 50 and higher are recommended to have 7 servings of fruits and vegetables per day.

Since it has been established that frequency of food intake can be used as a proxy for a quantified intake of fruit and vegetable consumption (Traynor et. al., 2006), we identified the four groups of intake the following way: 0 to 2 servings were considered ‘very low’ fruit and vegetable consumption, 3 to 6 ‘low’, 7 to 10 ‘adequate’ and 11 or more servings per day ‘high’ fruit and vegetable consumption.

Covariates / Independent Variables

Several demographic characteristics (gender, age, education, household level income and food security self-assessment) and health behavioural variables (self-perceived mental health, self-perceived health, physical activity levels, smoking, alcohol use, sleeping behaviour and self-reported body mass index (BMI)) were selected for inclusion, based on the evidence that they demonstrate potential to confound the relationship between diet and depression.

Total household annual income was classified into five income brackets: less than $20,000, $20,000 to $39,999, $40,000 to $59,999, $60,000 to $79,000, and more than $80,000 (all values are in Canadian dollars). Highest education in the household was grouped as less than secondary school, secondary school and postsecondary diploma or university degree. Levels of physical activity as identified by the Canadian Physical Activity Guidelines (CPAG) were grouped as physically active at/above recommended level from CPAG and physically active below recommended level from CPAG. BMI (excluding pregnant women) was derived from self-reported weight and height. It is calculated by dividing weight in kilograms by the square of height in metres. Based on Canadian guidelines for adults, BMI is classified into six categories:

Underweight (BMI less than 18.5); normal weight (BMI 18.5 to 24.9); overweight (BMI 25.0 to 29.9); obese class I (BMI 30.0 to 34.9); obese class II (BMI 35.0 to 39.9); obese class III (BMI greater than or equal to 40.0).

Alcohol consumption was assessed with the question "During the past 12 months, how often did you drink alcoholic beverages?". Results (less than once a month, once a month, 2 to 3 times a week, 4 to 6 times a week, every day) were recoded into three categories: "regular drinker" (drank once per month or more in the past year), "occasional drinker" (drank less than once per month in the past year) or 'non-drinkers' (no drink in the past year).

Smoking status was established with the question "At the present time, do you smoke cigarettes every day, occasionally or not at all?"

Sleep behaviour was established with the question "How long do you usually spend sleeping each night? As per National Sleep Foundation recommendations (Hirshkowitz et al., 2015), sleep time duration was recoded into three categories where 7 to 9 hours is considered adequate sleep duration, below 7 hours is considered short sleep duration and 9 hours or more is considered high sleep duration.

Food security status was assessed using The Household Food Security Survey Module (HFSSM) of the CCHS. The HFSSM is a standardized and validated scale of food insecurity severity that measures inadequate or insecure access to food due to financial constraints. The HFSSM was developed by the U.S. Department of Agriculture (USDA) for use in the United States, and was subsequently approved by Health Canada to become the measurement tool for household food insecurity in Canada.

The module itself consists of 18 questions on the experiences of food insecurity in a household over the previous 12 months. These experiences range from worrying about running out of food before there is money to buy more, to the inability to afford a balanced diet, to missing meals, and in extreme cases, going a whole day without eating because of a lack of food and money for food. The questions on the HFSSM distinguish between the experiences of adults and children.

Canada's official classification system defines food secure households as those with zero or one affirmative response on either the adult or child scale of the HFSSM. Moderately food insecure households are those with two to five affirmative responses on adult scale and two to four affirmative responses on child scale. Severe food insecurity is classified when there are six or more affirmative responses on adult scale and five or more affirmative responses on child scale (Health Canada, 2012). For the purpose of our study we only relied on the adult scale.

All of the above variables were categorized according to the CCHS database, with the exception of age grouping, which was collapsed and excluded people younger than 20 years old; fruit and vegetable consumption, which was categorized based on the recommendations from Canada's Food Guide (Katamay et al., 2001); depression scale, which was dichotomized based on the recommended depression severity scale published by Spritzer et al. (1999) to identify 'mild', 'moderate' and 'major depressive disorder'; satisfaction with life was recoded in three groupings; education that was recoded as '8' for people with less than secondary education, '12' for people who have completed high school but have no post-secondary school education and '16' for people who have post-secondary certificate diploma or university degree.

Owing to the fact that it is always difficult to conclude causal relationship based on this retrospective cross-sectional data-set (as depressed individuals might change their eating habits

secondarily to their depression as well as a certain diet can lead to depression), we will examine the relationship between fruit and vegetable consumption and depression both ways – in Model 1 depression will act as dependent variable, where impact of fruits and vegetables and socio-demographic and health characteristics on depression will be explored. Model 2 will test reverse causality as fruits and vegetables will act as dependent variable and depression and other socio-demographic and health characteristics as predictors.

Analysis

The data analysis was carried out using IBM SPSS and Oxmetrics. Results of regression and correlation were tested for considered statistical significance at the 1 % level where $p<0.01$.

We started with the complete data set from the 2015-16 data collection (with a sample of 130,000 respondents). Then we deleted individuals who had chosen not to complete questions on depression, on fruit and vegetable consumption and on satisfaction with life. After that we deleted individuals with missing values for any of the other explanatory variables (gender, age, education, income, physical activity, smoking and drinking behaviour, number of hours spent sleeping at night, BMI, food insecurity, perceived general health and perceived mental health). This resulted in a data set of 25,063 individuals for further analysis.

The data analysis involved several steps. The first step consisted of descriptive statistics that were calculated for all demographic and health questions. Participants were placed into depressed or not depressed categories using cut-offs of 15 points or more, which is an indication of major depression disorder and requires immediate treatment (Spitzer et al., 1999). The PHQ-9 at cut-points of 5 (mild), 10 (moderate), seldom occur in individuals with major depression and

do not require treatment (Kroenke & Spitzer, 2002). Data was cross-tabulated with aforementioned demographic variables to describe differences between certain age groups, sexes, and comparisons between education, income level of the respondents as well as health characteristics. One-way ANOVA analysis was used to determine bivariate associations of depression and fruit and vegetable consumption. Characteristics of participants were compared among those with and without depression with the Pearson chi-squared test for categorical variables and t-test for continuous variables. For correlation coefficients three levels of depression severity were examined – mild (cut off point ≥5), moderate (cut off point ≥10) and major depressive disorder (cut off point≥15).

Following this step, five separate linear and maximum likelihood regressions were run. Separate models were created for depression, fruit and vegetable consumption and life satisfaction. Models were stratified by confounding factors determined in previous research.

The primary focus of this step was to identify how depression (depression scale and life satisfaction) is linked to fruit and vegetable consumption (as an approximation of diet quality) and demographic and behavioural variables were linked to. In achieving objective 1 (the possible linkages between mental health and fruit and vegetable consumption), the fruit and vegetable intake score was linked to depression score. To allow for reverse causality these were estimated with either mental health or fruit and vegetable consumption (dietary quality) as dependent variables.

The second outcome of interest was life satisfaction. First the linkages (both ways) were assessed for life satisfaction and dietary quality; second, the linkages between life satisfaction, mental

health and dietary quality were assessed. This allowed fruit and vegetable consumption (dietary quality) to affect life satisfaction directly and indirectly through mental health variables.

Findings

Socio-demographic characteristics of the study population

Table 1 presents socio-demographic characteristics of the study population. Participants who did not respond were not included in the analysis. The total sample size included was approximately 25,063 out of a total of 130,000 who are surveyed by Statistics Canada.

Consistent with the official Census data (Statistics Canada, 2017), the biggest proportion of the population is in the age group between 60 and 69 (19.6%); the smallest proportion of the population are in the age group of 80-years old and above (3.6%). Official data from the Census 2016 also reports that for the first time in 2016, the share of seniors of the total Canadian population (16.9%) exceeded the share of children (16.6%). The increase in the proportion of seniors is likely to be a trend that will continue in the future (Statistics Canada, 2017). This trend will likely change some of the health outcomes both physical and mental health that will need to be dealt with in the future.

Given that women have a longer life expectancy than men, the aging of the Canadian population is also changing the distribution by gender. Statistics Canada reported that 50.9% of the total population were female in 2016 Census (Statistics Canada, 2017). The CCHS data from the same year accounted for 47.5% men as opposed to 52.5% women.

Census data from 2016 reports that more than half (54.0%) of Canadians aged 25 to 64 had postsecondary diplomas or university degrees in that year, making Canada first among the Organisation for Economic Co-operation and Development (OECD) countries in the proportion of college and university graduates (Statistics Canada, 2017). Data from the CCHS-2016 reports

that 88.9% of respondents from the age group between 20 to 69 year old had postsecondary diplomas or university degrees so our sample of survey respondents is better educated than the Census would suggest.

Table 1 | sociodemographic characteristics of participants of CCHS 2016 and depressive symptoms

Characteristics	%	Census 2016 (%)	Depression		p-value*
			Yes	**No**	
Gender	**n=25,063**		**n=594**	**n=24,469**	.000
Male	47.5	49.1	35.2	47.8	
Female	52.5	50.9	64.8	52.2	
Age	**n=25,063**		**n=594**	**n=24,469**	.000
20 to 29	13.9	12.9	17.7	13.8	
30 to 39	16.5	13.1	18	16.5	
40 to 49	16.5	13.1	22.2	16.4	
50 to 59	19.5	15.1	25.9	19.3	
60 to 69	19.6	12.1	10.8	19.8	
70 to 79	10.4	6.9	4.2	10.5	
80+	3.6	2.2	1.2	3.6	
Education	**n=25,063**		**n=594**	**n=24,469**	.000
Less than secondary school	6.9	18.3	13.5	6.8	
Secondary school only	17.0	26.5	24.4	16.9	
Postsecondary diploma or univ degree	76.0	55.3	62.1	76.4	
Income[ɔ]	**n=25,063**		**n=594**	**n=24,469**	.000
<$20,000	8.0	31.1	31.5	7.5	
$20,000-$39,999	15.4	25.6	20.4	15.3	
$40,000-$59,999	15.9	18.2	13.3	16	
$60,000-$79,999	14.7	10.6	12	14.7	
$80,000 or more	46.0	22.6	22.9	46.6	

*p-value was calculated using Chi square test

[b] Percentages may not add up to 100% due to rounding; participants who did not respond to a question were not included in the analysis of that question

[ɔ] All values in Canadian dollars.

The proportion of women (52.1%) who have postsecondary diploma or university degree is higher than for men. Official data from the 2016 Census reports that 54% of women had a university certificate, diploma or degree at bachelor level or above in 2016 (Authors interpretation of the table - Statistics Canada, 2016 Census of Population, Statistics Canada Catalogue no. 98-400-X2016242).

The 2016 Census of population reports that the median total income of Canadian households is $70,336 (Statistics Canada, 2017). Data from CCHS-2016 is similar as the majority of the population in that survey (46%) reported earning $80,000 or more per household, thus our sample is representative of the underlying population in terms of income.

Comparison of CCHS-2016 to the 2016 Census of the population reveals that respondents of CCHS-2016 differ from the general Canadian population in many ways – they are slightly older, more educated, more well-off and the majority are females. It is important to remember that our results cannot be directly extrapolated to the entire Canadian population. However, this is not unusual with surveys and many other studies have had the same pattern of responses being slightly older and better educated and more well-off demographic than the Canadian population as a whole (Matin et al., 2012) since these groups are in general more inclined to complete surveys. However, these results are still relevant to the Canadian population, given the size of the sample and the relative consistency between the characteristics of this sample and the Census descriptors.

Health related characteristics

Table 2 presents the health-related characteristics of our subset of participants of CCHS 2016. Most of the health characteristics investigated in this study are compared to other data sources

such as the General Social Survey, Cycle 30, 2016 [Canada]: Canadians at Work and Home (Statistics Canada, 2016) and Cycle 5 of the Canadian Health Measures Survey. Data for the Cycle 5 of the Canadian Health Measures Survey was conducted from January 2016 to December 2017. The target population consisted of persons 3 to 79 years of age living in the 10 provinces, and the target sample size of cycle 5 was 5,700 respondents. Data for the 2016 GSS were collected from August 2nd to December 23rd, 2016. The target population for the survey is non-institutionalized persons 15 years of age or older, living in the 10 provinces. Approximately 20,000 respondents were included in the 2016 GSS.

A majority of the respondents of the CCHS 2016 cycle were non-smokers (80.6%), General Social Survey (GSS-2016) reports similar results – 84.9% non-smokers. Overall, males were more likely (51.3%) to smoke cigarettes daily than females (48.7%). GSS reports slightly different results – 49.8% of males and 50.2% of females were daily smokers in the GSS 2016.

According to our subset of CCHS-2016 data, most Canadians drank alcohol once per month or more in the past year (58.3%). 22.6% of the respondents drink less than once a month, 20.9% drink 2-3 times per week and 7.5% drink 4 to 6 times a week. As with smoking, males were more likely (60.5%) to report consumption of alcohol 4 to 6 times per week than females (39.5%). The highest proportion of drinking every day was reported among those aged 60-69 (29.4%).

Table 2 | Health characteristics of participants of CCHS 2016 and depressive symptoms

Characteristics (comparator study number in brackets after variable name)	n (%)	Other studies[2]	Depression		p-value*
			Yes	**No**	
Physical activity level (2)	**n=25,063**	**n=5,700**	**n=594**	**n=24,469**	.000
Physically active at / above recommended level from CPAG	71.1	16.6	64.3	71.3	
Physically active below recommended level from CPAG	28.9	83.4	35.7	28.7	
Type of smoker (1)	**n=25,063**	**n=19,548**	**n=594**	**n=24,469**	.000
Daily	14.7	10.4	37.4	14.1	
Occasional	4.7	4.8	5.4	4.	
Not at all	80.6	84.9	57.2	81.2	
Type of drinker (1)	**n=25,063**	**n=19,534**	**n=594**	**n=24,469**	.000
Regular	67.2	67.5	52.7	67.5	
Occasional	16.6	15.2	23.7	16.5	
Non-drinker	16.2	17.4	23.6	16	
Body mass index (2)	**n=25,063**	**n=5,700†**	**n=594**	**n=24,469**	.000
Underweight	1.5		2.9	1.4	
Normal weight	39.4	40[a]	33.2	39.5	
Overweight	35.5	34	25.9	35.7	
Obese	23.7	27	38	23.3	
Self-perceived mental health (1)	**n=25,041**	**n=19,522**	**n=594**	**n=24,447**	
Excellent	33.4	25.9	2.4	34.2	.000
Very good	38.3	36.7	8.1	39.1	
Good	21.6	29	24.7	21.5	
Fair	5.2	6.8	34.7	4.5	
Poor	1.4	1.6	30.1	0.7	
Perceived general health (1)	**n=25,044**	**n=19,538**	**n=592**	**n=24,452**	.000
Excellent	22.9	15.6	3.4	23.4	
Very good	39.3	36	12	39.9	
Good	27.2	35.7	230.7	27.1	
Fair	8.2	10.3	29.9	7.6	
Poor	2.4	2.4	24	1.9	
Household food security (3)	**n=25,063**	**n=126,401**	**n=594**	**n=24,469**	.000
Food secure	97.6	87.7	90.2	97.8	
Moderately food insecure	1.1	7.4	2.9	1	
Severely food insecure	1.3	4.9	6.9	1.2	
Sleeping behaviour	**n=25,063**		**n=594**	**n=24,469**	.000
Short sleep duration (<7hrs)	78.4	N/A	81.1	78.3	

[2] Health and other characteristics investigated in this study were compared to the data from:
(1) General Social Survey, Cycle 30, 2016 [Canada]: Canadians at Work and Home (Statistics Canada, 2016)
(2) Canadian Health Measures Survey (CHMS) from 2016 and 2017
(3) Data from USDA "Household Food Security in the United States in 2016"

Adequate (7<9)	20.4	N/A	14	20.6
High sleep duration (9-12+hrs)	1.2	N/A	4.9	1.2
Satisfaction with life (1)	**n=25,063**	**n=19,461**	**n=594**	**n=24,469**
Dissatisfied/very dissatisfied	1.4	2.4	23.9	0.9
Neither satisfied nor dissatisfied	24.9	30.6	62.1	24
Satisfied/very satisfied	73.7	66.9	14	75.1
Fruits and vegetables	**n=25,063**		**n=549**	**n=24,469**
Very low (0 to 2 times/day)	41.2	N/A	56.9	40.8
Low (3 to 6)	49.4	N/A	35.3	49.7
Adequate (7 to 10)	7.9	N/A	6.6	8
High (11+)	1.5	N/A	1.2	1.5

† Canadian Health Measures Survey is a survey of Canadians aged 3–79

[a] Underweight and normal weight categories were combined in the Canadian Health Measures Survey

Results from the GSS-2016 are in accord with this statistic as they report that 7.6% of Canadians consume alcohol 4 to 6 times a week and 16.2% consume alcohol 2-3 times a week. Gender differences of alcohol consumption are similar to those reported in CCHS-2016: 56.4% of males consume alcohol 4 to 6 times a week as opposed to 43.6% females. The biggest proportion of every day alcohol consumption, according to the 2016 GSS falls in the 65 to 74 age group.

More than a half (71.1%) of the Canadian population included in the sample were classified as ‘physically active at or above the recommended level from the Canadian Physical Activity Guidelines (CPAG)’. In contrast, Cycle 5 (January 2016 to December 2017) of the Canadian Health Measures Survey indicates that less than 2 in 10 (16.6%) Canadian adults aged 18 to 79 met the recommended guidelines. In order to achieve health benefits, the recommendation for adults 18 and over is to accumulate at least 150 minutes of moderate to vigorous physical activity per week made up of sessions of activity each lasting at least 10 minutes. In the CCHS-2016 74.6% of men and 68% of females met the CPAG guidelines. There were no significant differences in levels of physical activity when comparing younger age groups: 20 to 29 (78.1%),

30 to 39 (73.9%), 40 to 49 (71.8%), and as expected starting with the age group 60 to 69 (69.8%), 70 to 79 (64.1%) and 80+ (53.2%) there was a decline in levels of physical activity.

This difference between CCHS-2016 and data in the Canadian Health Measures Survey might be due to the fact that CCHS is a self-report survey, while The Canadian Health Measures Survey directly measures the physical activity level of Canadians by using an activity monitor.

The prevalence of obesity among Canadians aged 18 and over was 23.7 in 2016 CCHS. The prevalence of obesity differed according to several sociodemographic characteristics.

Overall obesity levels were slightly higher for males (50.5%) than for females (49.5%). Age was also related to obesity. Considering both sexes together, those aged 20 to 29 (9.7%), 70 to 79 (9%) and 80+ (2%) were less likely to be obese than any other age group. Older adults, those aged 50 to 59, were the most likely to be obese (22.1%). Obesity levels also differ by household level educational attainment, 36.7% of people with less than secondary education are of normal weight and 26.7% are obese. In comparison, more people who have post-secondary degree tend to be of normal weight (40.2%) and less are obese (22.7%).

Results from the Canadian Health Measures Survey from 2016 and 2017 vary, this survey reports that 40% of Canadians are of normal weight, 34% are overweight and 27% are obese. According to the data from Canadian Health Measures Survey, obesity increases with age – 20% of people in the 18-39 year old age group are obese, while obesity rates in the 40-59 and 60-79 age groups are 31% and 33% respectively.

This discrepancy in numbers is not surprising. Estimates of obesity based on self-reported data, like CCHS, tend to be lower than estimates based on measured data because of biases in how

people report their weight and height. It is also known that Canadians tend to under-report their weight (Schermel et al., 2014).

In the Canadian Health Measures Survey height and weight are measured and used to calculate BMI (The Daily 2018, Stats Canada Canadian Health Measures Survey: Household and physical measures data, 2016 and 2017).

Most respondents reported self-perceived mental health as either 'excellent' (33.4%) or 'very good' (38.3%) and perceived general health was mostly assessed as 'very good' (39.3%). These results are comparable with the 2016 General Social Survey (GSS) - 25.9% of people rated their mental health as 'excellent' and 36.7% rated it as 'very good'. General health in the GSS-2016 was mostly rated as 'very good' (36%) as well.

Satisfaction with life

When asked to rate their general satisfaction with life on a scale from 0 to 10, Canadians on average in 2016 gave it a 7.4 grade, higher than the OECD average of 6.5 (OECD, 2013). The CCHS data from 2016 reports that 73.7% of respondents were 'satisfied' or 'very satisfied' with their life in general, that is those who scored 8 or more on 11-scale, and the mean level of satisfaction in 2016 was 8.13. These findings are quite consistent with other surveys, for example the 2016 GSS reports that 66.9% of the population are either 'satisfied' or 'very satisfied with life' and mean level of satisfaction with life as a whole is 7.86 (GSS, 2016).

Overall, there was no difference in life satisfaction between sexes in – 73.2% of males and 74.1% of females reported being 'satisfied' or 'very satisfied with life'. Results from the 2016

GSS also show that there is no gender differences in the level of satisfaction with life – 65.8% of males and 67.9% of females are either ‘satisfied’ or ‘very satisfied with life’.

People in the age group between 70 to 79 (both sexes) were the most likely to report being ‘satisfied’ or ‘very satisfied with life’ – 77%. The people in the age group between 50 to 59 is the least satisfied with life – 71.3% reported that they are ‘satisfied’ or ‘very satisfied with life’.

Table 3 | Relationship between satisfaction with life, severity of depression and fruit and vegetable consumption

	Dissatisfied/ very dissatisfied with life (%)	Neither/nor (%)	Satisfied/very satisfied with life (%)	
Depression (n=25,063)				
Not Depressed (0 to 4 points)	20.6	58.2	87.8	79.5
Mild (5 to 9 points)	21.5	25.9	10.0	14.1
Moderate (10 to 14 points)	17.8	10.1	1.7	4.0
Moderately severe (15 to 19 points)	19.8	4.4	0.4	1.6
Severe depression (20 to 27 points)	20.3	1.5	0.1	0.7
Fruit and vegetable consumption (n= 25,063)				
Very low (0-2 servings/day)	59.6	49.1	38.2	41.2
Low (3-6 servings/day)	34.5	43.1	51.8	49.4
Adequate (7-10 servings/day)	4.8	6.5	8.5	7.9
High (11+ servings/day)	1.1	1.3	1.5	1.5
	100%	100%	100%	100%

Life satisfaction scores in the GSS-2016 also vary depending on age and they are very similar to our sample. The GSS-2016 reports that the most satisfied with life age group is 75 years and older (75.6%); and the age group of 45 to 54 year old is least satisfied with life (61.6%).

People who reported that their physical health is 'excellent' or 'very good' are more satisfied with life – 91.2% and 82.3% respectively. Only 23.5% of people who assessed their general health as 'poor' were 'satisfied' or 'very satisfied' with life. Additionally, respondents who reported that their mental health is 'excellent' were also much more likely to be 'satisfied' or 'very satisfied' with life (91%). Only 7.4% of people who rated their mental health as 'poor' were 'satisfied' or 'very satisfied' with life.

In comparison, data from 2016 GSS also reports that people who evaluated their general health as 'excellent' or 'very good' tend to be more satisfied with life – 83.2% and 76.5% respectively. Only 30.9% of those who rated their general health as 'poor' were 'satisfied' or 'very satisfied with life'.

2016 GSS also reports that people who evaluated their mental health as 'excellent' or 'very good' are more likely to be 'satisfied' or 'very satisfied' with life – 85.3% and 74.6% respectively. 14.5% of those who rated their mental health as 'poor' were 'satisfied' or 'very satisfied with life'.

Findings from CCHS-2016 are also consistent with other research studies (Strine et al., 2008). The study reports that 5.6% of U.S. adults reported that they were dissatisfied or very dissatisfied with their lives. As the level of life satisfaction decreased, the prevalence of fair/poor general health increased as did activity limitation, depressive symptoms and sleep insufficiency. The

prevalence of smoking, obesity, physical inactivity, and heavy drinking also increased with decreasing level of life satisfaction (Strine et al., 2008).

Depression

There were 25,063 people in the sample, of which 2.4% (n=594) were classified as having a major depressive episode (PHQ-9 ≥ 15). As shown in Table 1 and Table 2, individuals with current major depression were middle-aged and a greater proportion were females (64.8%). Those with current major depressive episode were also more likely to be more educated and earn a household income of either <$20,000 or >$80,000. A higher proportion of respondents who were not meeting the recommended levels of physical activity were depressed, overweight or obese and on average had less than 7 hours of sleep (81.1%). Those with a current major depressive episode were more likely to have unhealthy behaviours, like smoking or being a regular drinker. Finally, a higher proportion of respondents who rated their perceived mental health and physical health as 'excellent' or 'very good' were not experiencing major depressive episode as compared to those who rated their general and mental health as 'fair' or 'poor'.

The above findings are quite consistent with the current literature. For example, a study conducted by Jorgensen et al. published similar results (Jorgensen et al., 2018). In this study individuals with a summed score ≥ 10 were defined as having depression on PHQ-9 scale. There were 11,624 people in the analytic sample, of which 8.6% were classified as having depression. Individuals with current depression were younger, and a greater proportion were female, were more likely to have a high school degree or less, earn a household income <35,000, be less physically active and exhibit higher BMI.

The original study published by Spritzer and the colleagues had a sample of 3000 cases. The mean age of the patients was 46 years, with a range of 18 to 99 years; 66% were female; 25% were college graduates. The most common types of physical disorders were hypertension (25%), arthritis (11%), diabetes (8%), and pulmonary disease. Diagnostic results of this study report that overall, 28% of the subjects had a PHQ diagnosis, of which 15% had a threshold diagnosis and 13% a subthreshold diagnosis only. 7% of the patients included in the analysis had probable alcohol abuse/dependence (Sptitzer et al., 1999).

Food security

Most of the people in the CCHS-2016 have consistent, dependable access to sufficient food required for healthy living – 97.6% were food secure, while 1.1% were moderately food secure and 1.3% were food insecure (based purely on the adult scale).

USDA monitors the extent and severity of food insecurity in U.S. households through an annual, nationally representative survey conducted by the U.S. Census Bureau. As in the Canadian version of food security module in CCHS, the food security status of each interviewed household is determined by the number of food-insecure conditions and behaviors the household reports. However, the threshold for moderate food insecurity is one affirmation less in Canada than the U.S. The results of the 2016 survey reveal that 89.5% of U.S households with no children were food secure throughout the year (based on 10-item adult food security scale). The remaining 10.5% were food insecure, of which 4.9% of households had very low food security (Coleman-Jensen et al., 2017).

Fruit and vegetable consumption

The average frequency of fruit and vegetable consumption per day was 3.81 in 2016 from the CCHS. Canada's Food Guide at the time (the 2007 version) recommends that female teens and adults consume 7-8 serving of vegetables and fruit per day and males consume 7-10 servings (Katamay et al., 2007).

Examination of the socio-demographic characteristics for the respondents of the CCHS 2016 cycle reveled significant differences in respondents' age, gender, education, income and fruit and vegetable consumption.

In accordance with the reviewed literature, on average men consume less fruits and vegetables per day (mean 3.31) than women (mean 4.27). This male versus female variation was also statistically significant ($p<0.001$, $r = 203$). According to Statistics Canada, this is true for other years too. From 2001 to 2014, females were more likely than males to consume more fruit and vegetables than men (Government of Canada, 2016).

Only 7.9% of Canadians reported consuming the recommended frequency (7 to 10 times per day) of fruits and vegetables.

Keeping in mind that the majority (49.4%) of the Canadian population in 2016 had low (3 to 6 times per day) fruit and vegetable consumption, the age group of 30 to 39 reported the highest proportion of adequate (11.8%) and high (2.6%) fruit and vegetable consumption, which is 7 to 10 and 11 times per day or more respectively. The lowest fruit and vegetable consumption (0 to 2 times per day) was reported in the age group of 20 to 29 year-olds – 35.9%. Low fruit and

vegetable consumption (3 to 6 times per day) was mostly reported for seniors 80 years of age and older (73%).

As expected, income and food security status seems to be related to the amount of fruits and vegetables consumed. Frequency of intake of fruits and vegetables increased sharply, from the average 3.16 times per day for people who earn less than $20,000 to 4.04 times per day, when total household income exceed $80,000. Those who are food secure also reported higher numbers of fruits and vegetable consumption (mean 3.83) as compared to severely food insecure people (mean 2.90).

Consistent with the findings of previous research (Lahti-Koski et al., 2002, Lowry et al., 2000) the frequency of eating fruits and vegetables was associated with other health related behaviours, such as physical activity. People who are physically active at or above the physical activity guidelines (mean 4.08), also eat more fruits and vegetables than those who are less active (mean 3.52) or not active at all (mean 3.30).

On average, people with normal weight (mean 3.99) or underweight (mean 4) consume more fruits and vegetables as opposed to those who are obese (mean 3.60).

Daily fruit and vegetable consumption was higher among those who assessed their mental health (mean=4.02) and general health (mean=4.28) as ‘excellent’.

In the bivariate analysis, alcohol behaviour did not differ according to fruit and vegetable consumption and smoking behaviour was associated with small differences in fruit and vegetable consumption – those who smoke daily consumed on average 3.01 times per day of fruits and vegetables as compared to 3.98 average for those who didn’t smoke at all.

Bivariate analysis revealed that fruit and vegetable intake was correlated significantly with all our independent variables with the exception of age (Table 4). Fruit and vegetable consumption was correlated positively with life satisfaction, smoking status (which is coded 1=smoking and 3 = non-smoking), number of hours per night spent sleeping, income, education, gender (female), perceived general health, perceived mental health; and correlated negatively with depression, BMI, physical inactivity, food insecurity, drinking and age.

Table 4 | Correlation for study variables

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1 Depression scale	–													
2 Fruits &vegetables	–.086**	–												
3 BMI	.061**	–.066**	–											
4 Perceived health	–.376**	.119**	–.183**	–										
5 Perceived mental health	–.482**	.088**	–.047**	.465**	–									
6 Life satisfaction	–.475**	.119**	–.048**	.464**	.510**	–								
7 Physical inactivity	.046**	–.096**	.048**	–.109**	–.044**	–.055**	–							
8 Food insecurity	.142**	–.042**	.023**	–.085**	–.097**	–.110**	–.002	–						
9 Smoking	–.161**	.146**	.044**	.159**	.123**	.157**	.016**	–.082**	–					
10 Drinking	.053**	–.009	.011	–.147**	–.053**	–.057**	.079**	–.034**	–.010	–				
11 Sleeping	–.202**	.021**	–.047**	.109**	.085**	.136**	.005	–.019*	.084**	–.025**	–			
12 Income	–.165**	.107**	.019**	.229**	.164**	.208**	–.071**	–.127**	.164**	–.229**	.020**	–		
13 Education	–.085**	.109**	–.033**	.177**	.118**	.103**	–.068**	–.080**	.150**	–.154**	.022**	.363**	–	
14 Gender (female)	.091**	.203**	–.115**	.009	–.039**	.021**	.073**	.011	.040**	.111**	.025**	–.092**	–.018**	–
15 Age	–.122**	–.001	.079**	–.131**	.033**	.029**	.099**	–.071**	.115**	.127**	.015*	–.138**	–.186**	.014*

Depression

Bivariate analysis shows that the covariates were also associated with another outcome of interest – depression. Fruit and vegetable intake is negatively correlated with the level of the depression scale (correlation coefficient r= –.086, p<0.01).

Being female (r=.091, p<0.01), younger (r = – .122, p<0.001), spending less hours of sleep at night (r = – .202, p<0.001), having less income (r = – .165, p<0.001) or being food insecure (r = .142, p<0.001) and having higher BMI (r = .061, p<0.01) was associated with depression.

A negative association was found between depression and perceived general health (r = – .376, p<0.01) and perceived mental health (r = – .482, p<0.01) in bivariate correlation analysis, which of course makes sense because these three aspects are closely related to depression.

Life satisfaction

Table 3 displays descriptive statistics and correlations of different levels of depression severity, fruit and vegetable consumption with life satisfaction. Satisfaction with life appears to be significantly correlated with both fruit and vegetable consumption (r = 119, p<0.01) and depression (r = – 475, p<0.01).

The results suggest that the respondents who were ‘satisfied’ or ‘very satisfied with life’ more often tend to have adequate fruit and vegetable consumption as compared to those who were either ‘dissatisfied’ or ‘very dissatisfied with life’.

With regards to the depression scale, people who were ‘satisfied’ or ‘very satisfied with life’ are less likely to be depressed – 87.8%. Those who were dissatisfied’ or ‘very dissatisfied’ with life

were more likely to be either categorized as not depressed (20.6%) or mildly depressed (scored 5 or more, does not require treatment).

To further emphasize the linkage and potential impact of fruit and vegetable consumption during the last month on self-reported depression, impact of fruit and vegetable consumption on life satisfaction, as well as estimate whether there is an association between fruit and vegetable intake, depression and life satisfaction, five linear regression models were constructed. Results of linear regression and Tobit analyses are shown in Table 5 and Table 6.

Association between fruit and vegetable consumption and depression

Table 5 & 6, Model 1 shows the regression results for the linkages between depression and fruit and vegetable intake after controlling for all potential confounders.

Results indicate that several covariates (being female, being younger, having less education, having less income, being food insecure, having higher BMI, being a regular smoker, sleeping less hours per night, being less physically active) were significantly associated with depression.

In this model, all covariates, besides drinking behaviour, were associated with mental health (depression) in adults. The association between the presence of self-reported depressive symptoms and the consumption of fruits and vegetables was statistically significant (coefficient = – .102, $p<0.001$). As expected higher fruit and vegetable consumption is associated with lower depression.

Table 5 | Ordinary Least Squares Linear regression analysis

Independent variable	Dependent variable									
	Model 1 Depression		Model 2 Fruits and vegetables		Model 3 Fruits and vegetables		Model 4 Satisfaction with life		Model 5 Satisfaction with life	
	Coefficient estimate	t	Coefficient estimate	t	Coefficient estimate	t	Coefficient estimate	t	Coefficient estimate	t
Female	.825***	17.278	1.018***	34.855	.980***	33.704	.195***	10.723	.047*	2.353
Age	–.313***	–22.097	.012	1.329	.020*	2.220	–.012*	–2.28	.044***	7.381
Education	–.040***	–3.748	.059***	8.919	.059***	9.006	.229961E-02	.574	.941384E-02*	2.123
Income	–.178830E-04***	–18.734	.626176E-05***	10.486	.590058E-05***	9.825	.698173E-05***	19.198	.101863E-04***	25.491
Food insecurity	1.371***	14.600	–.131*	–2.222	–.142*	–2.422	–.163***	–4.555	–.408***	–10.385
BMI	.352***	12.249	–.111***	–6.195	–.116***	–6.482	–.022*	–2.056	–.085***	–7.107
Smoking (1=daily, 3=not at all)	–.525***	–15.809	.358***	17.326	.356***	17.231	.122***	9.676	.216***	15.556
Drinking	.069*	2.199	.018	.652	.013	.659	–.015	–1.273	–.028*	–2.092
Sleep	–.546***	–31.104	–.019	–1.705	–.012	–1.127	.046***	6.722	.143***	19.506
Physical inactivity	.278***	5.415	–.527***	–16.569	–.524***	–16.451	–.088***	–4.511	–.138***	–6.396
Depression			–.039***	–10.035			–.179***	–74.968		
Fruits and vegetables	–.102***	–10.035					.029***	7.514	.047***	11.101
Satisfaction with life					.104***	11.101				
Constant	8.757***	37.462	2.185***	14.672	1.212***	7.778	7.587***	83.480	6.018***	61.494
Adjusted R-square	.124		.091		.092		.256		.089	
N	25,063		25,063		25,063		25,063		25,063	

Data source: Canadian Community Health Survey, 2016

[a] *p<0.05, **p<0.01, ***p<0.001

Table 6 | Tobit regression analysis

Independent variable	Dependent variable									
	Model 1 Depression		Model 2 Fruits and vegetables		Model 3 Fruits and vegetables		Model 4 Satisfaction with life		Model 5 Satisfaction with life	
	Coefficient estimate	t	Coefficient estimate	t	Coefficient estimate	t	Coefficient estimate	t	Coefficient estimate	t
Female	1.389***	18.463	1.021***	34.899	.982***	33.736	.196***	10.727	.047*	2.350
Age	–.530***	–23.675	.012	1.353	.020*	2.256	–.013*	–2.342	.044***	7.330
Education	–.048**	–2.914	.059***	8.952	.060***	9.38	.244250E-02	.607	.958025E-02*	2.153
Income	–.257736E-04***	–17.325	.631***	10.551	.594630E-05***	9.890	.698695E-05***	19.152	.102033E-04***	25.4526
Food insecurity	1.662***	11.836	–.132*	–2.236	–.143**	–2.445	–.164***	–4.570	–.410***	–10.399
BMI	.554***	12.356	–.110***	–6.133	–.115***	–6.426	–.022*	–2.012	–.085***	–7.069
Smoking (1=daily, 3=not at all)	–.705***	–13.814	.360***	17.376	.357***	17.285	.123***	9.679	.217***	15.559
Drinking	.021	.424	.012	.608	.012	.614	–.015	–1.271	–.028*	–2.099
Sleeping	–.852***	–31.408	–.018	–1.600	–.011	–1.006	.046***	6.670	.144***	19.488
Physical inactivity	.461***	5.746	–.529***	–16.594	–.525***	–16.476	–.088***	–4.493	–.138***	–6.380
Depression			–.040***	–10.151			–.180***	–74.977		
Fruits and vegetables	–.175***	–10.816					.029***	7.480	.047***	11.073
Satisfaction with life					.110***	11.181				
Constant	10.151***	28.011	2.165***	14.516	1.182***	7.574	7.585***	83.195	6.010***	61.216
McFadden Pseudo R-squared	0.02905381		0.0212198		0.021412		0.07868345		0.024967	
Sigma	5.269***	161.282	2.256***	223.641	2.255***	223.641	1.374***	223.182	1.520***	223.167

Data source: Canadian Community Health Survey, 2016

[a] *p<0.05, **p<0.01, ***p<0.001

To test the possibility of reverse causality, fruits and vegetables were used as dependent variable in Model 2. In this model, the coefficient estimate for depression indicated a strong association as well (coefficient = – 039, $p<0.001$). In line with other studies regarding healthy eating habits, education is a significant predictor (coefficient = .059, $p<0.001$), gender (coefficient = 1.018, $p<0.001$), BMI (coefficient = –.111, $p<0.001$), smoking (coefficient = .358, $p<0.001$) and physical activity (coefficient = –.527, $p<0.001$) for diet quality.

Of interest, the number of hours spent sleeping, alcohol consumption and age were not associated with fruit and vegetable intake. Generally, the pattern of association was similar for depression as predictor of fruit and vegetable intake and fruit and vegetable consumption as predictor of depression. This indicates that this relationship is in fact bi-directional.

Association between satisfaction with life and fruit and vegetable consumption and depression

Table 5 & 6, Model 4 and Model 5 test satisfaction with life and its linkages to dietary quality (through fruit and vegetable consumption) and mental health. After controlling for all potential confounding factors, there was evidence of strong association between satisfaction with life and fruit and vegetable consumption.

The results showed that fruit and vegetable consumption had both direct and indirect effect on life satisfaction. However, after adjusting satisfaction with life model for depression (Model 4), the relationship between fruit and vegetable intake and life satisfaction slightly weakened from (coefficient = .047, $p<0.001$ to coefficient = 029, $p<0.001$).

In Model 5 when satisfaction with life models are adjusted for confounding factors, age, income, smoking and sleeping have strong positive association, while food insecurity, BMI and physical inactivity have strong negative associations with life satisfaction.

When the model is adjusted for depression (Model 4), gender (coefficient = 195, $p<0.001$) becomes effect modifiers on satisfaction with life. Age and BMI on the other hand become less significant, and education loses significance.

Discussion

In the present study, our objective was to analyze the relationship between depression and fruit and vegetable consumption as well as association between depression, fruit and vegetable consumption and satisfaction with life among Canadian population in 2016. We found strong negative associations between the frequency of fruit and vegetable consumption and depression; positive relationships between the frequency of fruit and vegetable consumption and satisfaction with life; and with each of the frequency of fruit and vegetable consumption(positive) and depression (negative) and life satisfaction.

It is challenging to establish the influence of broader diet quality on population mental health, partly because of complex interplay between nutrients and also because of confounding by other lifestyle behaviours associated with changes in dietary habits. Besides, dietary exposure is prone to measurement error, has many intervening and mediating factors that cannot be excluded and is prone to self-report and desirability bias. Nonetheless, there is a growing body of evidence form cross-sectional (Ribeiro et al., 2017, Kingsbury et al., 2015), dietary intervention trials (Jacka et al., 2017) and systematic reviews and meta-analysis (Lassale et al., 2019, Glabska et al., 2020) that support the protective effect of fruits and vegetables (as does this study).

The expectation that fruits and vegetables positively impact mental health is supported by physiological pathways. One of the plausible mechanisms explaining why fruits and vegetables may confer protective benefits, is their high content of antioxidants and essential micronutrients that are likely to be protective (Akbaraly et al., 2009). Antioxidants defend against the negative effects of oxidative stress (such as neuronal damage), which has been associated with depression (Berk et al., 2008). And micronutrients like magnesium may reduce inflammation and protect

against chronic inflammation which is implicated in depression (Berk et al., 2013). Fruit and vegetable consumption might influence these inflammation processes and in turn, prevent depression. Studies also show that a diet rich in fruits and vegetables generates a high fibre intake that has positive effect on gut microbiota, which in turn is associated with better mental and cognitive health (Calvani et al., 2018). Moreover, recent human studies (Jacka et al., 2015) suggest an impact of diet on neurotrophins, neurogenesis and hippocampal function. Fruits and vegetables have been associated with better metabolic health outcomes which share a common etiology with depression (Lassale et al., 2019).

Our results are consistent with and build upon the literature showing that high fruit and vegetable intake is inversely associated with poor mental health and increased risk of depression (Saghafian et al., 2018, Jacka et al., 2011). However, adequate fruit and vegetable consumption was remarkably low in the Canadian population in 2016, only 7.9% of the adult population were meeting Canada's Food Guide recommendations of eating 7 to 10 times of fruits and vegetables per day. The results have significant implications for public health, given that previous cross-sectional studies in the US and Canada reported positive association between high fruit and vegetable intake and lower mental distress (e.g. Ribeiro et al., 2017, Kingsbury et al., 2015).

The present study demonstrates an association between high fruit and vegetable consumption and higher level of satisfaction with life. Consistent with these findings, data from a recent cross-sectional analysis also indicated that those with higher dietary quality were more likely to report good well-being, even after adjustments for confounding factors (Meegan et al., 2017). A systematic review of 61 observational studies also reported that fruits and/or vegetables have

positive effect on mental health through decrease in depressive symptoms as well as improvement in well-being and enhancement of happiness (Glabska et al., 2020).

Concordant with cross-sectional studies and systematic reviews, a randomized controlled trial design was applied in the "SMILES" study – a rigorous intervention study explicitly designed to take a dietary approach to treatment in populations with existing mental disorders. The study investigated the efficacy of a dietary program for the treatment of major depressive episodes and found that dietary improvement may indeed provide an efficacious and accessible treatment strategy for the management of depression (Jacka et al., 2017).

Our results support the former studies in that fruit and vegetable consumption showed strong protective effects on depression scores. The associations between fruit and vegetable intake and depression remained significant however was attenuated after adjusting for the effects of important confounders, including gender, age, income, food insecurity status, education, drinking, smoking, sleeping, BMI and physical activity.

Smoking, alcohol

Several other studies have accounted for the effects of lifestyle factors such as physical activity, smoking, alcohol consumption and diet quality (Kingsbury et al., 2015, Jacka et al., 2011) on depression. However, the covariance between health behaviours such as diet, physical activity and smoking complicates the assessment of the diet-mental health relationship as these health behaviours are all associated with depression in a bidirectional manner (Jacka, 2016). Although these health behaviours are also correlated with each other, the regression results show unique influences of each factor on depression. Fruit and vegetable intake remains important even when other factors are accounted for.

In particular, alcohol consumption has consistent associations with mental health disorders. In addition to these associations, the Diagnostic and Statistical Manual of Mental Disorders, 5th edition (DSM-V) lists alcohol-induced mental disorders, including alcohol-induced depressive disorders, thus building causality into the disorder category (DSM-V, 2013).

Rehm and the colleagues have recently summarized the possible descriptions of the potential causal pathways that underlie the association between heavy alcohol use and alcohol use disorders and major depressive disorders (Rehm et al., 2017). According to the study published in 2017, these pathways are: (a) heavy drinking/alcohol use disorders cause depressive disorders; (b) depressive disorders increase alcohol use and cause alcohol use disorders ('self-medication'); and (c) a reciprocal causal relationship or causation by another mechanism such as genetic vulnerability. Rehm concludes that all three mechanisms are possible and probably existing, but the first mechanism—that alcohol use (especially heavy use and alcohol use disorders) causes depression—is stronger and more prevalent than the other pathways (Rehm et al., 2017).

Interestingly, our findings are somewhat inconsistent with previous literature that suggests that alcohol consumption is predictive of depression or has negative associations with fruit and vegetable consumption. Alcohol was not a significant factor in any of our models. One potential explanation could be that the measurement of alcohol consumption is prone to reporting error and may be influenced by cultural differences (Lahti-Koski et al., 2002).

Evidence about the relationship between alcohol consumption and psychological well-being and life satisfaction is still mixed and debated. For example, a cross-cultural study conducted by Grant and the colleagues also found that while life satisfaction was positively associated with not smoking, physical exercise and eating fruit, but was not related to alcohol consumption (Grant et

al., 2009). Evidence from a Russian study suggest that reasonable consumption of alcohol improves the level of life satisfaction, while alcohol abuse produces negative effects on life satisfaction.

Regarding smoking, our findings are consistent with past research showing that smoking has been associated with lower consumption of fruits and vegetables (Lahti-Koski et al., 2002).

Smoking is also associated with increased risk of depression (Pasco t al., 2008), decreased levels of satisfaction with life (Grant et al., 2009) and is associated with worse cognitive and mental health (Gehlich et al., 2018). Our results show the same findings.

Physical activity and BMI

Regarding physical activity, our results underlined that depressed individuals are more likely to be inactive. These findings corroborate results from previous studies showing reduced physical activity levels in depressed individuals (Ribeiro et al., 2017). Additionally, a recent study found a trend towards a worsening combined effect of depression and obesity on physical activity reduction (Sander et al., 2018).

Many previous studies highlighted that obesity is associated with more anxiety, stress and depression (Murabito et al., 2013, Oddy et al., 2018). In our study, BMI was positively associated with higher depression scores, and negatively associated with fruit and vegetable consumption, and satisfaction with life. These results are consistent with the previous literature.

The relationship between BMI and depression is complex and not definitive, however it seems relevant to highlight most recent lines of reasoning. Several factors are involved in a biological pathway. First, obesity can be seen as an inflammatory state where weight gain is shown to

activate inflammatory pathways (Murabito et al., 2013) and inflammation in turn has been associated with depression (Miller et al., 2002). Thus, inflammation appears to play an important role in both adiposity and depressive symptoms and may be one mediator of the association between the two conditions where the effects of this relationship is bidirectional (Pan et al., 2012). However, Oddy and the colleagues have found strong evidence that inflammation precedes depression (Oddy et al., 2018). Second, obesity creates additional risks of developing diabetes mellitus and increased risk of insulin resistance (Pan et a., 2012), which could induce alterations in the brain and increase the risk of depression (Ajilore et al., 2007). In addition to biological mechanisms, psychological pathways can play a role too. Being overweight and the perception of overweight can increase psychological distress (Atlantis & Ball, 2008).

Overall, we found that physical activity was a strong predictor for depression, life satisfaction and fruit and vegetables consumption. Individuals who exercise regularly, tend to consume a healthier diet, including fruits and vegetables. This is in accordance to previous findings (Lowry et al., 2000, Markussen et al., 2016).

Satisfaction with life is a key determinant of happiness throughout the lifespan and is related to people's physical and mental health (Pavot & Diener, 2008) so it is not surprising that it is influenced by levels of physical activity. This finding is similar to current research that shows that engaging in regular physical activity is indirectly associated with improved satisfaction with life (Elavsky et al., 2005). In our study as well significance of physical activity was attenuated when depression scale was introduced. Scores on the satisfaction with life have been shown to correlate with measures of mental health in our study as well as many others (e.g. Pavot & Diener, 2008). Therefore, as tempting as it may seem to attribute association between improved

satisfaction with life to the physical health benefits of physical activity, research indicates that physical activity indirectly enhances satisfaction with life through its influence on affect, physical self-worth, self-efficacy, and mental health (Elavsky et al., 2005). Observational data have demonstrated that regular exercise is protective against depression, while physical inactivity is a risk factor for developing depression. For example, Jacka and the colleagues found that regular physical activity in childhood was related to reduced likelihood of depression in adulthood (Jacka et al., 2011). The results of various meta-analyses also indicated that exercise has a moderate to large antidepressant effect (e.g. Josefsson et al., 2014). The promising evidence that physical activity can prevent future depression has important implications for public health.

Sleep duration

Our results are in contrast to some human studies that show associations between fruit and vegetable consumption and sleep duration (Stamatakis & Brownson, 2008) because no significant association between fruit and vegetable intake and sleep was found in our study.

Short sleep duration is associated with risk behaviors that are known to promote weight gain and obesity including lower physical activity and poor food choices such as increased fat intake (Shi et al., 2008) and increased intake of energy from snacks (Nedeltcheva et al., 2009) and lower fruit and vegetable consumption (Stamatakis & Brownson, 2008). The path to weight gain via short sleep duration may operate through interrelationships with obesity-related behaviors that may act as mediators or moderators in the causal pathway (Kraemer et al. 2001).

Sleep duration is associated with depression and has indirect effect on life satisfaction (through depression) as it is known that sleep duration may be directly impacted (i.e., either shortened or

lengthened) by physical and mental illness (Stamatakis & Brownson, 2008). In agreement with our results, a recent meta-analysis found that short and long sleep duration was significantly associated with increased risk of depression (Zhai et al., 2015).

Socio-demographics

Food choice is an area in which research has revealed consistent behavioural gender differences and, in general, women have been frequently reported to engage in far more health-promoting behaviours than men and have healthier lifestyle patterns (Arganini et al., 2012). Our findings are consistent with past research showing that women on average tend to report a significantly higher frequency of fruits and vegetables intake than males (Wardle et al., 2004, Riediger et al., 2007).

A factor that could contribute to gender differences in food choice is women's greater concern about weight control and their higher frequency of dieting. Wardle and the co-workers also suggest that men believe eating healthily is important to some degree, just not as strongly as women and that men as a group are simply less enthusiastic about the benefits of healthy eating (Wardle et al., 2004).

It was hypothesized that there would be a difference between sexes in mental health disorders, such as depression, that are more common among women than men. This was found to be true as gender was a significant predictor in our depression regression model. Gehlich and colleagues also found in their study that being female, being older were in general associated with worse mental health (Gehlich et al., 2018).

Literature suggests that there is a tendency to consume less fruits and vegetables with age (Kanungsukkasem et al., 2009, Gehlich et al., 2018). However, it was not a significant predictor in our study.

Consistent with past research, we found that individuals who earned more on average reported higher levels of life satisfaction (Cheung & Lucas, 2015), this may be because income predicts many additional factors that would be expected to be associated with subjective well-being. Higher socio-economic groups also tend to value health more than lower socio-economic groups (Kamphius et al., 2015) and therefore people with high incomes are more likely to have better health and a higher standard of living (Cheung & Lucas, 2015) that would allow them to have a healthier diet.

In agreement with previous studies, food insecurity is associated with depression and negatively associated with fruit and vegetable consumption (Tarasuk, 2001). Food insecurity has been linked to poorer self-perceived general and mental health and low life satisfaction in a Canadian study based on the 2004 CCHS Nutrition cycle (Willows et al., 2011). Previous research suggests that food insecurity may be adding additional stress contributing to mental health problems, and that food insecurity leads to lower diet quality and micronutrient deficiencies in turn may affect symptoms of anxiety and depression as they provide the brain with less key nutrients (Weaver & Hadley, 2009).

Lower income families consume less fruits and vegetables (Giskes et al., 2004) due to perception that fruits and vegetables are expensive, have a short life shelf, or are difficult to store (Kamphius et al., 2006). Similarly, another Canadian study based on CCHS cycle 2.1 found

similar results where household education and income independently had a significant positive impact on fruit and vegetable intake (Riediger et al., 2007).

Besides, lower income families are more likely to live in disadvantaged neighbourhoods with fewer grocery stores and smaller convenience stores might not offer healthful foods at affordable price (Oliver & Hayes 2005). Interventions to improve opportunities for sufficient fruit and vegetable consumption for low income families are necessary.

Poor dietary choices are linked not solely to lack of purchasing power but to educational attainment. For example, a study carried out by Wilde and the colleagues reported that when stipends were given to low-income families, they did not make healthy choices but rather continued to purchase the same unhealthful food in larger quantities (Wilde et al., 1999). In the current study, linear regression analysis revealed that education was a strong predictor for fruit and vegetable intake and depression, which is consistent with prior work that lower education levels are associated with higher intake of energy dense but nutrient poor foods, while higher education levels are associated with nutrient rich foods (Finger et al., 2013, Wilde et al., 1999).

In sum, income seems to be a decisive factor in many health related behaviours that lead to health inequalities as it influences standard of living, education and psychological stress. It is argued that income inequality remains the main cause of mental health problems (Ribeiro et al., 2017) making the reduction of social injustice a number one propriety for public health.

Limitations

The main challenge of this study is that inferences about dietary quality were made on fruit and vegetable consumption data rather than data on diet overall. For some variables like BMI self-reported data may be biased. It is also known that Canadians tend to under-report their weight, people may not know their height or weight or their response may reflect perceived social and cultural norms about the ideal height and weight (Schermel et al., 2014) so that self-reported data used to calculate BMI suggest lower values of obesity and overweight prevalence than measured data.

The nutrition questions in the Canadian Community Health Survey (CCHS) address only fruit and vegetable consumption, no information is available about other food groups. The questions ask about the number of times fruits or vegetables are consumed, but not about amounts consumed. Because the questions do not specify portion sizes, compliance with daily intake recommendations, such as those in the Canada Food Guide, are not assessed. At the same time, single item fruit and vegetable consumption items have been shown to correlate with comprehensive dietary recall measures and are widely used in research (Garriguet, 2009).

An important methodological limitation is that PHQ-9 is a self-reported measurement of depression and our study was limited in that no clinical depression assessment was available. Nevertheless, the PHQ-9 has been commonly used in epidemiological studies and is widely accepted as an appropriate tool for the measurement of depression (Meader et al., 2011).

Lastly, no inference for causality could be done as cross-sectional study design limits this ability - the exposure (fruit and vegetable consumption) and outcome (depression and life satisfaction)

are measured at the same time, and therefore it is not possible to say which is cause and which is effect.

A significant body of evidence is present to suggest that dietary patterns are relevant to mental health illness. At the same time, future research is required to explain the impact as well as additional pathways of different diets and healthy eating indexes on mental health. It would also be of value to test different depression scales and linking the data to nutrition.

Additional research is also required in understanding the etiology of depression that would clarify the relationship between obesity and depression, and food security and depression. These relationship appears to be bi-directional but understanding which condition came first have important implications for public health.

Continued research is also needed to translate the evidence base into public health recommendations and clinical practice. The cost of mental health treatments is an enormous burden on society, therefore health economists could assist with calculating and comparing health care cost of conventional treatment programs and alternative treatment approaches in this emerging field of ‘nutritional psychiatry’ (Kaplan et al., 2015).

Conclusion

The findings of this study offer further support for the role and importance of a healthy diet that is comprised of fruits and vegetables for the prevention and management of depression and improvement of overall well-being.

The study provides evidence for a bidirectional association of dietary quality (through high fruit and vegetable consumption) and mental health, in a way that higher dietary quality can play protective role in the onset of depression. On the other hand, poor diet (like low fruit and vegetable intake) is independently associated with a greater likelihood of depressive illness onset as depression can promote unhealthy eating. Even though there are some longitudinal studies that have suggested that reverse causality is a less likely explanation for long-term associations (Port et al., 2012), the exact mechanisms linking depression and diet quality cannot be entirely explained and remain rather correlative, as behavioural changes might determine meal choice before depression occurs. From a public health perspective, it is important to know if dietary improvement may prevent depression and further research is needed to identify the direction of this relationship.

According to the Canadian Mental Health Association, one in five Canadians will experience a mental health condition such as depression, anxiety or bipolar disorder in his/her lifetime. It has become so common that it is estimated that by age 40, about 50% of the population will have or have had a mental illness (Mental Health Commission of Canada, 2013).

People with mental health disorders suffer from considerable distress or disability with an additional risk of a harmful or poor outcome, such as pain, increased risk of suicide as well as all

causes disability or death (Mental Health Commission of Canada, 2013). While mental health disorders are commonly known for their impact on health and well-being, social disfunction and psychological distress (Lépine & Briley), they also have an economic impact in terms of absenteeism, loss of productivity, unemployment and medical expenses. Worldwide projections by the World Health Organization for the year 2030 identify unipolar major depression as the leading cause of disease burden and are among the main causes of disability worldwide (WHO, 2004). In Canada, the economic burden of mental illness is estimated at $51 billion per year. This includes health care costs, lost productivity and reductions in healthrelated quality of life (Mental Health Commission of Canada, 2015).

Currently there are no dietary recommendations regarding mental health disorders available in Canada, while pharmacological interventions are prescribed to about 85% of patients with depression (Wong et al., 2014). However, this type of treatment may require long-term treatment and cause significant adverse effects (Bet et al., 2013). Recent epidemiologic evidence has been accumulated to suggest that certain lifestyle factors are the drivers of mental health and an individual's satisfaction with life and well-being. Therefore, modifiable risk factors such as improved nutrition, promotion of physical activity and smoking cessation could be effective strategies for mental health management and prevention that will lead to both – improvement in health and cost reduction. At the very least, dietary interventions can be considered as part of the treating package to manage depression and the enormous burden of mental health illness. For example, counselling therapies for depressed individuals could be accompanied by a nutrition education or registered dietitian ready to use program.

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Appendix

Table A | Household food security status

Was that often true, sometimes true, or never true in the past 12 months? (often true, sometimes true, never true)

Food security items	Affirmative responses CCHS 2016 (%)	USDA 2016
Household items		
Worried that food would run out (FSC_010)	10.1	16.2
Food bought would not last (FSC_015)	8.5	13.3
Could not afford to eat balanced meals (FSC_020)	9.4	12.9
Adult items		
Adult(s) cut size or skipped meals (FSC_040)	36.7	7.5
Respondent ate less than should have (FSC_050)	38.2	7.7
Respondent hungry but did not eat (FSC_055)	22.3	4.0
Respondent lost weight (FSC_060)	15.7	2.4
Adult(s) not eat for a whole day (FSC_065)	19.9	1.7

Table B | Socio-demographic and health characteristics and fruit and vegetable consumption of the participants of CCHS 2016 (n ≈ 25,000)

Characteristic	Mean	SD	t
Gender			.000
Male	3.31	2.08	
Female	4.27	2.51	
Physical activity level			.000
Physically active at / above recommended level from CPAG	3.96	2.46	
Physically active below recommended level from CPAG	3.46	2.06	
Type of smoker			.000
Daily	3.01	2.14	
Occasional	3.55	2.20	

Not at all	3.98	2.38	
Type of drinker			.315
Regular	3.83	2.34	
Occasional	3.81	2.37	
Did not drink in the last 12 months	3.76	2.44	
Age			.000
20 to 29	3.69	2.71	
30 to 39	3.98	2.49	
40 to 49	3.85	2.38	
50 to 59	3.74	2.29	
60 to 69	3.76	2.27	
70 to 79	3.83	2.01	
80+	3.95	2.00	
Sleeping behaviour			.214
Short sleep duration	3.81	2.37	
Adequate	3.85	2.29	
High sleep duration	3.64	3.16	
Education			
Less than secondary school	3.18	2.13	.000
Secondary school only	3.43	2.21	
Postsecondary diploma or univ degree	3.96	2.39	
Income[a]			.000
<$20,000	3.16	2.39	
$20,000-$39,999	3.55	2.14	
$40,000-$59,999	3.76	2.34	
$60,000-$79,999	3.79	2.35	
$80,000 or more	4.04	2.41	
Body mass index			.000
Underweight	4.02	2.62	
Normal weight	3.99	2.47	
Overweight	3.74	2.26	
Obese	3.61	2.31	
Perceived mental health			.000
Excellent	4.02	2.48	
Very good	3.84	2.26	
Good	3.63	2.31	
Fair	3.28	2.22	
Poor	3.07	2.51	
General health			.000
Excellent	4.28	2.62	
Very good	3.83	2.28	
Good	3.55	2.19	
Fair	3.38	2.19	
Poor	3.43	2.82	
Food security (adult)			.000
Food secure	3.86	2.33	

Moderately food insecure	3.55	2.47
Severely food insecure	2.90	2.53