3-29-2021

Association of habitual intake of fruits and vegetables with depressive symptoms: The AusDiab study

Simone Radavelli-Bagatini
Edith Cowan University

Reindolf Anokye
Edith Cowan University

Nicola P. Bondonno
Edith Cowan University

Marc Sim
Edith Cowan University

Catherine P. Bondonno
Edith Cowan University

See next page for additional authors

10.1007/s00394-021-02532-0
This is a post-peer-review, pre-copyedit version of an article published in European Journal of Nutrition. The final authenticated version is available online at: http://dx.doi.org/10.1007/s00394-021-02532-0
Radavelli-Bagatini, S., Anokye, R., Bondonno, N. P., Sim, M., Bondonno, C. P., Stanley, M. J., . . . Blekkenhorst, L. C. (2021). Association of habitual intake of fruits and vegetables with depressive symptoms: The AusDiab study. *European Journal of Nutrition*, *60*(7), 3743-3755.
https://doi.org/10.1007/s00394-021-02532-0

Authors

Simone Radavelli-Bagatini, Reindolf Anokye, Nicola P. Bondonno, Marc Sim, Catherine P. Bondonno, Mandy J. Stanley, Craig Harms, Richard Woodman, Dianna J. Magliano, Jonathan E. Shaw, Robin M. Daly, Jonathan M. Hodgson, Joshua R. Lewis, and Lauren C. Blekkenhorst

Association of habitual intake of fruits and vegetables with depressive symptoms: the AusDiab Study

Simone Radavelli-Bagatini[1*#], Reindolf Anokye[1*], Nicola P. Bondonno[1,2], Marc Sim[1,2], Catherine P. Bondonno[1,2], Mandy Stanley[3], Craig Harms[4], Richard Woodman[5], Dianna J. Magliano[6,8], Jonathan E. Shaw[7,8], Robin M. Daly[9], Jonathan M. Hodgson[1,2], Joshua R. Lewis[1,2,10*] and Lauren C. Blekkenhorst[1, 2*]

[1]Institute for Nutrition Research, School of Medical and Health Sciences, Edith Cowan University, Perth, WA, Australia

[2]Medical School, The University of Western Australia, Perth, WA, Australia

[3]School of Medical and Health Sciences, Edith Cowan University, Perth, WA, Australia

[4]School of Arts and Humanities, Psychology and Criminology, Edith Cowan University, Perth, WA, Australia

[5]Flinders Centre for Epidemiology and Biostatistics, Flinders University, Adelaide, SA, Australia

[6]Diabetes and Population Health, Baker Heart and Diabetes Institute, Melbourne, VIC, Australia

[7]Clinical Diabetes and Epidemiology, Baker Heart and Diabetes Institute, Melbourne, VIC, Australia

[8]School of Public Health and Preventive Medicine, Monash University, Melbourne, VIC, Australia

[9]Institute for Physical Activity and Nutrition, School of Exercise and Nutrition Science, Deakin University, Melbourne, VIC, Australia

[10]Centre for Kidney Research, Children's Hospital at Westmead, School of Public Health, Sydney Medical School, The University of Sydney, Sydney, NSW, Australia

*These authors contributed equally

[#]Corresponding author:

Simone Radavelli-Bagatini

School of Health and Medical Sciences

Medical Research Foundation (MRF)

50 Murray St. (rear), Perth 6000 AUSTRALIA

Tel: +61 8 9224 0344

E-mail: s.radavellibagatini@ecu.edu.au

ORCID: 0000-0001-6821-5217

Short running head: Fruit and vegetable intake and depressive symptoms

Declarations

Funding

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors. The salary of LCB is supported by a National Health and Medical Research Council (NHMRC) of Australia Emerging Leadership Investigator Grant (ID: 1172987) and a National Heart Foundation of Australia Post-Doctoral Research Fellowship (ID: 102498). The salary of JRL is supported by a National Heart Foundation of Australia

Future Leader Fellowship (ID: 102817). The salary of JMH is supported by a National Health and Medical Research Council of Australia Senior Research Fellowship (ID: 1116973). JES is supported by an NHMRC Investigator Grant (ID: 1173952). None of the funding agencies had any role in the conduct of the study; collection, management, analysis, or interpretation of the data; or preparation, review, or approval of the manuscript.

Ethics statement

The study was approved by The Human Research Ethics Committees of the International Diabetes Institute, and the Alfred Hospital (Melbourne, Australia).

Data Availability

The data that support the findings of this study were available from the Baker Heart and Diabetes Institute, under a license agreement. Data will be available from the Principal Investigator of AusDiab upon reasonable request and approval of the AusDiab Steering Committee.

Authors' contributions

SRB, RA, LCB, JRL and JMH designed the statistical analysis of the study, planned the statistical analysis, interpreted the results and extensively reviewed the manuscript. SRB and NPB analysed the data. RW assisted with the statistical analyses. SRB and RA reviewed the literature and prepared the manuscript. NPB, MS, CPB, CH assisted with the methodology and interpretation of the results. SRB, RA, NPB, MS, CPB, MJS, CH, RW, DJM, JES, RMD, JMH, JRL, LCB had significant input and critically reviewed and approved the final manuscript.

Acknowledgements

The AusDiab study, initiated and coordinated by the International Diabetes Institute, and subsequently coordinated by the Baker Heart and Diabetes Institute, gratefully acknowledges the support and assistance given by:

A Allman, B Atkins, S Bennett, S Chadban, S Colagiuri, M de Courten, M Dalton, M D'Emden, T Dwyer, D Jolley, I Kemp, P Magnus, J Mathews, D McCarty, A Meehan, K O'Dea, P Phillips, P Popplewell, C Reid, A Stewart, R Tapp, H Taylor, T Welborn, F Wilson and P Zimmet.

Also, for funding or logistical support, we are grateful to: The Commonwealth Dept of Health and Aged Care, Abbott Australasia Pty Ltd, Alphapharm Pty Ltd, AstraZeneca, Aventis Pharmaceutical, Bristol-Myers Squibb Pharmaceuticals, Eli Lilly (Aust) Pty Ltd, GlaxoSmithKline, Janssen-Cilag (Aust) Pty Ltd, Merck Lipha s.a., Merck Sharp & Dohme (Aust), Novartis Pharmaceutical (Aust) Pty Ltd., Novo Nordisk Pharmaceutical Pty Ltd, Pharmacia and Upjohn Pty Ltd, Pfizer Pty Ltd, Roche Diagnostics, Sanofi Synthelabo (Aust) Pty Ltd., Servier Laboratories (Aust) Pty Ltd, BioRad Laboratories Pty Ltd, HITECH Pathology Pty Ltd, the Australian Kidney Foundation, Diabetes Australia, Diabetes Australia (Northern Territory), Queensland Health, South Australian Department of Human Services, Tasmanian Department of Health and Human Services, Territory Health Services, Victorian Department of Human Services, the Victorian OIS program and Health Department of Western Australia. RA is supported by an Australian Government Research Training Program Scholarship (International).

ABSTRACT

Purpose: To investigate the relationship of habitual FV intake, different types of FV and vegetable diversity with depressive symptoms.

Methods: Australian men and women (n=4,105) aged >25 years from the Australian Diabetes, Obesity and Lifestyle Study were included. Dietary intake was assessed using a Food Frequency Questionnaire at baseline, 5 and 12 years. Depressive symptoms were assessed using the validated 10-item Centre for Epidemiology Studies Short Depression Scale at 12 years. Multiple logistic regression models were used to investigate the association between the exposures of interest and depressive symptoms using odds ratios (OR) and 95% confidence intervals (CI) across quartiles of FV intake and vegetable diversity. Analyses were multivariable adjusted for confounding factors.

Results: At 12 years, 425 (10.4%) participants had "any depressive symptoms". Habitual FV intake was inversely associated with depressive symptoms at 12 years. After adjustment, participants in quartile 2 of FV intake (Q2; median 317 g/day) had a 20% lower odds of having any depressive symptoms (OR [95%CI]: 0.80 [0.69, 0.95]) in comparison to those in the lowest quartile of FV intake (Q1; median 223 g/d). Yellow/orange/red and leafy green vegetables were the key vegetable types driving this association. Higher vegetable diversity (4-6 different vegetables per day) was associated with a 24-42% lower odds of having depressive symptoms when compared to <3 different vegetables per day. The associations remained similar after further adjusting for diet quality.

Conclusion: A FV-rich diet, consisting of a diverse range of vegetables, particularly yellow/orange/red and leafy green vegetables may help to lower depressive symptoms. Promoting such a diet, particularly in men and women with a low FV intake, may have a significant public health impact.

Keywords: AusDiab, Australian adults, fruits and vegetable intake, vegetable diversity, depressive symptoms**.**

INTRODUCTION

Depression, also known as Major Depressive Disorder (MDD) or clinical depression. The two core features of MDD are persistent feeling of sadness and low mood as well loss of interest and pleasure [1]. Depression affects how individuals feel, think and behave and can lead to several emotional and physical problems [1]. Depression affects more than 300 million people worldwide [2] and is one of the most common mental disorders in Australia [3,4]. It is the leading contributor to global disability [5] and cause of mental health-related disease burden [6]. Depression is estimated to be responsible for an average of 8.3 deaths by suicide per day among Australian men and women [7], and is also associated with an increased risk of other chronic diseases, particularly impaired cognitive functioning [8] and cardiovascular disease (CVD) [9].

Evidence shows that dietary interventions can reduce depressive symptoms [10]. One focus of research has been on the link between habitual intake of fruit and vegetables (FV) and depression. As background, it has been suggested that many vitamins, minerals and phytochemicals found in FV may serve a protective function for aspects of mood with greater consumption of FV being not only associated with lower oxidative stress and inflammation, but also associated with better healthy emotional and cognitive functioning [11]. Evidence suggests a link between FV intake and depression [12-21]. Diets high in fruit (total fruit with and without juice) and vegetables (specifically orange, dark green vegetables and legumes) [22,23,14] have been associated with lower depressive symptomology in different populations. Higher intakes of FV have been associated with fewer symptoms of depression among women in the United Kingdom [12] and for both men and women in Japan [13]. Further, the outcomes of Australian longitudinal studies indicate that consuming diets high in FV can improve mood regulation associated with depression [15], and that consuming higher quantities of salad (cucumber, lettuce), fresh vegetables (broccoli, carrots), and fruit (melon, peach, nectarines) was associated with lower depressive symptoms [16].

Although these studies have investigated the association of FV intake with depression in specific age populations, the association between long-term habitual FV consumption and depressive symptomology across the adult lifespan remains to be determined. Furthermore, the role of habitual intake of specific FV types as well as the habitual diversity of FV on symptoms of depression requires investigation, which may have significant impact on public health.

The primary aim of this study was to examine the associations between long-term habitual intake of FV and depressive symptoms among Australian men and women who were part of the Australian Diabetes, Obesity and Lifestyle (AusDiab) Study. Secondary aims were to: (1) examine the association between habitual intake of specific FV types (bananas; apples and pears; oranges and other citrus fruits; cruciferous vegetables; allium vegetables; yellow/orange/red vegetables; leafy green vegetables; and legume vegetables) and depressive symptoms; and (2) examine the association between diversity of vegetable intake and depressive symptoms.

METHODS

Study design

The Australian Diabetes, Obesity and Lifestyle (AusDiab) Study is a large longitudinal population-based study conducted among a diverse group of Australian adults aged 25 years and over, recruited in 1999-2000 and followed up in 2004-05 and 2011-12. A total of 11,247 men and women attended a biomedical examination (1999-2000), 6,400 returned for follow-up assessments at 5 years (2004-05), and 4,604 returned at 12 years (2011-12). Methods and response rates have been described previously [24].

Participants

From the 11,247 participants who were initially involved in the AusDiab study, we excluded those who did not complete the CESD-10 questionnaire at 12 years (n=6,768), those who did not complete the Food Frequency Questionnaire (FFQ) at baseline (1999-2000; n=42), and those who did not have at least two repeated measures for FV intake (i.e. those who responded to the FFQ at one time-point only; n=51). We also excluded those with implausible energy intakes (<3300 or >17,500 kJ in men and <2,500 kJ or >14,500 kJ in women; n=89), pregnant women (n=22), and those with missing data for covariates (n=170). After all exclusions (n=7,142), data from 4,105 participants were available for the association between habitual FV intake (main exposure of this study) and depressive symptoms at 12 years to be analysed. The consort flow diagram is shown in **Online Resource 1**. A written informed consent was obtained from all participants.

Measures

Dietary intake

FV intake was assessed using a 74-item FFQ developed by the Cancer Council of Victoria, Australia [25]. Participants self-reported their intake of different food groups including FV over the prior 12 months using 10 possible options ranging from "never" to "3 or more times per day". Nutrient intakes were calculated based on frequency of consumption in the previous 12 months and an overall estimate of usual portion size [25]. Energy intake from alcohol was also estimated using the FFQ [25], where frequency of consumption for alcohol ranged from ‘never’ to ‘every day’.

Fruit and vegetable exposures

Habitual intake was the average intake of FV, calculated as the sum of FV intake from at least two time-points (baseline, 5 years and 12 years follow-ups), divided by the number of time-points (i.e. baseline + 12-year FV intake)/ 2; or baseline + 5-year + 12-year FV intake)/ 3).

All types of fruits (except for fruit juice, tinned and dried fruits) and vegetables (except potato, roasted and fried, including hot chips) commonly consumed in Australia were assessed in the FFQ. Three types of fruits were included: i) bananas; ii) oranges and other citrus fruits; and iii) apples and pears (pome fruits), as per previous studies [26]. These are the most common fruits consumed in Australia [27]. Vegetable types were determined based on the 2013 Australian Dietary Guidelines [28], and were grouped according to their phytochemical profiles, as previously reported [29]. Briefly, vegetables were combined to form the following subgroups [30,29,31-34]: cruciferous vegetables (cabbage, Brussels sprouts, cauliflower, and broccoli); allium vegetables (onion, leek, and garlic); yellow/orange/red vegetables (tomato, capsicum, carrot, beetroot and pumpkin); leafy green vegetables (lettuce and other salad greens, celery, silver beet, and spinach); and legumes (peas, greens beans, bean sprouts and alfalfa sprouts, baked beans, soy beans, soy bean curd and tofu, and other beans). Habitual intake of the individual FV types was calculated in the same way as the habitual overall FV intake. Vegetable diversity was estimated using the following question from the FFQ: “How many different vegetables do you usually eat in a day?”, with responses ranging from “less than 1” to “6 or more”. The average of at least two time-points (baseline, 5 years and 12 years) were used to calculate the habitual vegetable diversity. An equivalent question to measure fruit diversity was not available from the FFQ. We were, therefore, unable to investigate fruit diversity in our study.

Depressive symptoms outcomes

Depressive symptoms at the 12-year follow-up were assessed using the self-reported 10-item Centre for Epidemiology Studies Short Depression (CESD-10) Scale [35]. The CESD-10 was developed to identify current depressive symptomatology related to major or clinical depression in adults and adolescents, and contains 10 questions about a person's feelings and behaviour over the previous week of completing the questionnaire [35]. Three statements focus on depressed affect (e.g., "I felt depressed"), five question evaluate other symptoms that are part of the diagnostic criteria for depression (e.g., "I could not get going"), or commonly associated with depression (e.g., "I had trouble keeping my mind on what I was doing"), and two items (which are reverse-scored) relate to positive affect (e.g., "I was happy") [36]. The CESD-10 includes questions such as "did you feel depressed", "did you feel afraid", and "were you happy". Respondents rated each symptom of depression as being "rarely or none of the time (less than 1 day)"; "some or a little of the time (1-2 days)"; "occasionally or a moderate amount of the time (3-4 days)"; or "most or all of the time (5-7 days)" on a four-point Likert scale. Scores on the CESD-10 can range from 0 to 30, with scores ≥10 indicating the presence of depressive symptoms [35,37]. In the present study, CESD-10 symptomology was categorised into two groups: no depressive symptoms (score <10) and any depressive symptoms (score ≥10). CESD-10 has been found to be a reliable instrument, presenting high internal consistency (Cronbach's α=0.86) and test-retest reliability (ICC=0.85) [38,39]. To test the internal validity of the CESD-10, we categorised question 3 ("do you feel depressed?") into two categories: no (n=3,351) and yes (n=754). We then examined the association between FV intake and this variable. Question 3 ("do you feel depressed?") was the most relevant question to the actual presence of depression.

Baseline data assessment

Demographic data was collected at baseline (1999-2000) through a household interview and included as covariates in the statistical analyses. Participants provided information on age (based on date of birth), sex (male/female), relationship status (de facto, married, separated, divorced, widowed, never married) education level (never to some high school, completed University or equivalent) and income (based on 6 categories of average weekly income: $0-199, $200-399, $400-599, $600-799, $800-1,499, and $1,500+).

Baseline body mass index (BMI) was calculated as weight (kg) divided by height (squared metres). Height was measured to the nearest 0.5 cm without shoes using a stadiometer. Weight was measured without shoes and excess clothing to the nearest 0.1 kg using a mechanical beam balance [40]. Details of anthropometric assessments have been published previously [41,24].

Participants self-reported their time spent performing physical activity in the previous week using the Active Australia Survey Questionnaire [42] as described previously [43]. Total physical activity (min per week) was calculated by summing the time spent walking (if continuous for ≥10 min) and/or performing moderate-intensity exercise. Time spent performing vigorous-intensity exercise was doubled (i.e. multiplied by two) and then added to the time spent walking and/or performing moderate-intensity exercise to obtain the total minutes of physical activity per week [44]. Physical activity levels were then classified as sedentary (no physical activity), insufficient (below 150 min per week and/or fewer than five sessions per week) and sufficient (above 150 min per week across at least five sessions).

Socio-Economic Indexes for Areas (SEIFA) were calculated according to relative socio-economic conditions per geographic area, based on the five-yearly Census [45] from 1999.

An interviewer-administered questionnaire [24] was used to assess smoking status. Participants were classified as: current smokers (smoking at least daily); ex-smoker (less than daily for at least the last three months); and never smokers (< 100 cigarettes during life) [46]. Self-reported history of CVD (yes/no) and diabetes mellitus (DM) based on plasma glucose levels (known DM, impaired fasting glucose, impaired glucose tolerance, new DM, normal glucose levels) were assessed as previously reported [24].

A dietary guideline index [47] reflecting adherence to 5 main food groups based on the Australian Dietary Guidelines [48,28] was calculated and used in our study to help us understand whether a healthy diet could potentially be a confounding factor in our study. The methodology of how this index was calculated has previously been described [47]. Briefly, the dietary guideline index included 15 components representing: 1) dietary variety; 2) fruit; 3) vegetables; 4) total cereals; 5) whole-grain cereals; 6) meat and alternatives (i.e. fish, poultry, nuts); 7) lean protein sources; 8) total dairy; 9) reduced/low fat dairy; 10) non-alcoholic beverages; 11) alcoholic beverages; 12) salt intake; 13) saturated fat; 14) added sugars, and; 15) extra foods [47]. A score of 0-10 (from lowest intakes to optimal intake or reaching the recommendations) was given to each component, with a possible total diet score ranging from 0-150 (higher score indicating greater compliance with the dietary guidelines) [47].

Statistical analyses

Analyses were undertaken using IBM SPSS (version 25; IBM, Chicago, IL, USA) [49], and R software (version 3.0.2) [50]. The main exposure of this study was total habitual FV intake (quartiles) and the main outcome was depressive symptoms (CESD-10). Logistic regression models were used to investigate relationships between the exposures of interest (habitual FV intake) and depressive symptoms (no symptoms vs. any symptoms). Odds ratios (ORs) and 95% confidence intervals (CIs) were estimated to compare the association between depression and the median of each quartile, with quartile 1 used as a reference value. To assess the linearity of the relationship between habitual FV intake and depressive symptoms, we also modelled the exposures as continuous variables with restricted cubic splines using the ‘rms’ R package with the rcs() function [51]. The overall effect of the exposure on the outcome for the cubic splines were obtained using Wald's tests. We tested for nonlinearity using a chi-squared test to compare nested models. Odds ratios with 95% CI bands were plotted for each unit increase in the exposure of interest (i.e. FV intake) using the median value in quartile 1 as the reference point. The x-axes of all graphs have been truncated at 3 SD above the mean for visual simplicity. Two models of adjustment were used in all analyses: (1) minimally adjusted for age and sex; and (2) multivariable adjusted for age (years), sex (men/women), BMI (kg/m^2), energy intake (kcal/day), relationship status (de facto, married, separated, divorced, widowed, never married), physical activity levels (sedentary, insufficient, sufficient), level of education (never to some high school, completed university or equivalent), SEIFA (socio-economic index for areas), smoking status (current smoker, ex-smoker, non-smoker), self-reported history of CVD (yes/no), and diagnosis of diabetes (yes/no). In sensitivity analyses, we further adjusted for income and adherence to the Australian Dietary Guidelines. These analyses were repeated for specific types of FV and habitual vegetable diversity, all entered into models as quartiles. Statistical significance was set at $p \leq 0.05$ (two-tailed) for all tests.

RESULTS

Baseline characteristics

Participants' flow chart is shown in **Online Resource 1**. Baseline characteristics of the 4,105 participants overall, and stratified by quartiles of habitual FV intake, are presented in **Table 1**. Briefly, 55.7% (n=2,285) were women and the mean (±SD) age of participants was 49 ± 11 years. The majority (53.9%) were considered sufficiently active, 10.7% were current smokers, 4.1% reported a history of CVD, and more than 80% presented with normal glucose levels.

At baseline, average energy intake was 2,022 ± 666 kcal/day (mean ± SD), and total FV intake was 380 ± 148 g/day. At 12 years, average CESD-10 score for depression was 4.0 ± 4.4: 10.4% (n=425) had "any depressive symptoms (CESD-10 score ≥10)" and 89.6% (n=3,680) had "no depressive symptoms (CESD-10 <10)". Of those participants with a CESD-10 score ≥10, 272 (6.6% of the overall sample) reported mild symptoms of depression (CESD-10 score 10-14)" and 153 of the participants (3.7% of the total sample) reported severe depressive symptoms (CESD-10 score >14).

Associations of habitual dietary intake of FV and types of fruit and vegetable intake with depressive symptoms at 12 years

The association between FV intake and depressive symptoms at 12 years was nonlinear (**Fig. 1**): the inverse association appeared to plateau at FV intakes of approximately 300 g/day (i.e. the relationship was somewhat "L-shaped"). Similar-shaped associations were seen for intakes of fruit and vegetables, discretely (Fig. 1).

Odds ratios for any depressive symptoms (CESD-10 score ≥10), by quartiles of FV intake, are shown in **Table 2**. For FV, participants in Q2 (median habitual intake of 317 g/day) had a 20% lower odds of depressive symptoms (OR [95% CI]: 0.80 [0.69, 0.95]), compared to participants in Q1 (median intake 223 g/day; Model 2; **Table 2**); ORs were not lower for higher intake categories, which is also reflected by the splines. For vegetable intake, those in Q2 (median intake 148 g/day) had 18% lower odds of depressive symptoms in comparison to those in Q1 (median intake 105 g/day) (**Table 2**). For question 3 of the CESD-10 ("do you feel depressed?"; no [n=3,351] and yes [n=754]), those in Q2 (median 317 g/day), Q3 (median intake 410 g/day) and Q4 (median intake 550 g/day) of FV intake had a 26% (OR [95% CI] 0.74 [0.65, 0.84]), 27% (0.73 [0.61, 0.87]) and 24% (0.76 [0.10, 0.95]) lower odds for depression, respectively, in comparison to those in Q1 (median intake 223 g/day).

The multivariable-adjusted cubic splines for associations between types of fruit and depression are shown in **Online Resource 2**. There was no evidence of an association between individual fruits (bananas, oranges and other citrus; or apples and pears) and depressive symptoms (**Table 3**).

Intakes of yellow/orange/red vegetables in Q3 (median intake 51 g/day) and Q4 (median intake 71 g/day) were associated with a 24% (0.76 [0.61, 0.95]) and 31% (0.69 [0.52, 0.92]) lower odds of depressive symptoms, respectively, in comparison to Q1 (median intake 25 g/day) (**Table 3**). A lower odds of depressive symptoms (38%) was also identified among those with a higher intake of leafy green vegetables (Q4; median intake 26 g/day: 0.62 [0.47, 0.82] vs. Q1; median intake 7 g/day). In addition, **Online Resource 3** shows the cubic spline-based association between the habitual intake of types of vegetables examined in the present study and symptoms of depression.

An average vegetable diversity of 4, 5 and 6 or more different types of vegetables per day was associated with a 24% (Q2: 0.76 [0.63, 0.92]), 42% and (Q3: 0.58 [0.43, 0.77]) 41% (Q4: 0.59 [0.43, 0.82]) lower odds of depressive symptoms, respectively, compared to 3 or less (**Table 4)**. In addition to the above findings, **Fig. 2** shows the cubic spline-based association between average vegetable diversity and depressive symptoms. We have also further adjusted the aforementioned analysis for vegetable intake and the associations remained significant, suggesting that the results are robust and independent of total vegetable intake (Q2: 0.74 [0.60, 0.92], Q3: 0.55 [0.39, 0.77], Q4: 0.54 [0.35, 0.84] vs. Q1).

Sensitivity analyses

We added income to the multivariable-adjusted model, as a further adjustment for socio-economic status. The association between consumption of FV and depressive symptoms (Q2: 0.81 [0.69, 0.95] vs. Q1) remained similar. To further explore whether an optimal healthy diet could be a confounding factor in our study, we added the dietary guideline index in the multivariable-adjusted model 2 (except for energy intake, which is accounted for in the dietary guideline index). Similar relationships were observed for FV intake and depressive symptoms, with those in Q2 (317 g/day) of FV intake having a 17% (0.83 [0.71, 0.98]) lower odds of presenting depressive symptoms compared to Q1 (223 g/day).

DISCUSSION

In this population-based cohort of Australian men and women, we found an association between higher habitual intake of FV and lower depressive symptoms. This relationship was non-linear, with the largest dietary benefit seen from increasing individuals' consumption beyond 250 g/day – the upper range of the lowest quartile. Our results showed that consuming sufficient amounts of vegetables is associated with lower depressive symptoms. When examining the associations of habitual intake of specific types of vegetables, a higher consumption of total vegetables, and in particular yellow/orange/red vegetables and leafy green vegetables, was associated with a lower odds of depressive symptoms at 12 years. Potential benefits of habitual intake of vegetables were observed for median intakes of ~148 g/day (~2 servings of vegetables per day).

Our findings support previous studies that reported associations between FV intake and depression [12-21]. A meta-analysis [52] reported that a higher intake of vegetables was associated with a 14% lower risk of depression in 9 prospective cohort studies, and 25% lower risk of depression in 16 cross-sectional studies. The same meta-analysis reported that for each 100 g/day higher in vegetable intake there was an associated 3% lower risk of depression in prospective cohort studies (RR=0.97; 95% CI 0.95, 0.98), and a 5% lower risk of depression in cross-sectional studies (RR=0.95; 95% CI 0.91, 0.98) [52].

Individuals with depression also have lower levels of certain nutrients found in FV, such as beta carotene, vitamin C, fiber, and folate [53-55], as well as higher oxidative stress and lower antioxidant capacity [56,57] than those without depression. In addition, the association between intakes of FV and depressive symptoms might be partly mediated by minerals and amino acids found in FV, which are precursors of particular neurotransmitters [58] (e.g. Gamma aminobutyric acid (GAMA), serotonin, norepinephrine and dopamine) that regulate mood [59]. The association may also be attributed to higher levels of 8-hydroxy-deoxyguanosine, a marker of oxidative damage to DNA, that has been found to be associated with depression [60]. Particular nutrients and phytochemicals found in FV, such as vitamin E, vitamin C, carotenoids, and nitrate, can reduce oxidative stress [61] and mitigate inflammation [62,63], both which are associated with depression [64], thereby potentially reducing the risk of depression [65,66] or reducing depressive symptoms [18].

The association between FV intake and depressive symptoms was also observed for specific types of vegetables; a higher habitual intake of yellow/orange/red vegetables and leafy green vegetable were each associated with lower odds of having depressive symptoms. The potential health benefits of vegetable compounds, such as lycopene present in red vegetables (i.e. tomatoes), could be attributable to their antioxidant activities that decreases oxidative stress and free radical cell damage [67], with potential benefits on depressive disorders [68]. Carotenoids, phytochemicals also present in yellow/orange/red and dark green leafy vegetables [69,30], reduce oxidative stress and inflammation, potentially through the activation of transcription factors, such as nuclear factor κB (NFκB) or nuclear factor erythroid 2-related factor 2 (Nrf2). Carotenoids may also influence transcription factors' targets (i.e. interleukin 8 [IL-8], prostaglandin E2 [PGE2], heme oxygenase [Hmox-1] and superoxide dismutase [SOD]) [70], which leads to a decrease in oxidative stress and inflammation. Leafy green vegetables are the richest source of dietary nitrate, which has been shown to reduce inflammation [63]. Dietary nitrate present in leafy green vegetables could, therefore, play a role in alleviating depressive symptoms. The reported consumption of green leafy vegetables and lower odds of experiencing depressive symptoms is in line with previous studies [14]. A cross-sectional study including 422 participants aged 18 to 25 years conducted in New Zealand and the United States, also reported an association between consuming vegetables, such as dark green leafy vegetables, and better mental health outcomes [22]. Similarly, a study including adolescents who participated in the Western Australian Pregnancy Cohort (Raine) Study reported a correlation between higher intakes of leafy green vegetables and more favourable mental health outcomes [23].

To the best of our knowledge this is the first observational study to investigate vegetable diversity and depressive symptoms in a large number of adults across the lifespan. In the current study, we found that consumption of a greater diversity of vegetables (≥4 types/day) was associated with a 24-42% lower odds of having depressive symptoms (CESD-10 score ≥10). Similarly, a randomised controlled trial that included Australian adults between the ages of 18–65 years reported that consumption of a diversity of vegetables and Mediterranean-style diet plus fish oil supplementation improved mental health ($r=-0.303$, $p=0.01$) [71]. Taken together, these results suggest that consuming ≥4 types/day of vegetables may contribute to lowering depressive symptoms.

Collectively, the findings from the present study support an association between FV intake and depressive symptoms, strengthening the findings from previous studies [72]. Currently, approximately 350 million people are affected by depression [73] and depression is predicted to outpace CVD as the number one cause of disease burden worldwide by 2030 [73]. Although diets rich in vegetables have been linked with more favourable mental health outcomes, only one in 13 Australians (7.5%) meet the recommended intake of ≥5 serves of vegetables per day in 2017-18 [74]. This highlights the importance of our results and the need to improve public health messages around increasing FV intake, in particular the consumption of specific types of vegetables and diversity of vegetables. These may be simple protective measures to prevent the onset of depression and/or improve mental health, and therefore of crucial importance given the increasing rate of depression worldwide. Given the global burden of depression [3] and its impact on quality of life [13], modifiable lifestyle factors, such as recommendations to increase FV intake, should be considered to help improve mental health [14].

Limitations of the study

A limitation of the study is observational nature which does not allow evidence for causality. Another limitation is that depressive symptoms were measured only once in 2011-2012 which means we cannot rule out the possibility for reverse causality (low intake of FV could be a consequence of depression) [72], although higher intakes of FV have previously been found to lower the risk of onset of depression [75]. In addition, there may be a possibility of selection bias given only 37% of the baseline participants remained after excluding those lost to follow up, or with missing data. Our results may not therefore be generalisable to all Australian adults. Residual confounding also remains a possibility, given the self-reported nature of data on FV consumption. A further limitation is that depression-related hormones, such as dopamine and cortisol, were not available in this study.

Strengths of the study

A major strength of the study is its large sample size, being one of the largest observational studies to analyse the association between types of FV intake and depressive symptoms in adults across a wide age range. This is the first observational study to report that a diverse range of vegetables are associated with a lower odds of depressive symptoms, which has significant implications for public health messaging. A further strength is the use of the same validated FFQ to assess dietary intake across all three time-points over a 12-year period which allowed us to generate a reliable measure for habitual FV intake. Depressive symptoms were measured using a well-established and validated questionnaire (CESD-10) and the detailed survey allowed us to account for a large number of important lifestyle confounders.

Conclusion

A habitual FV intake above that of the lowest quartile was associated with approximately 20% lower odds of having any depressive symptoms. Yellow/orange/red and leafy green vegetables, in particular, as well as consuming a variety of vegetables (4 or more types of vegetables per day) were associated with lower depressive symptoms. These associations were independent of factors known to be associated with a healthier lifestyle, such as being more physically active and not smoking. These results suggest that healthy diet rich in FV, with an emphasis on yellow/orange/red and leafy green vegetables, may benefit mental health. These benefits are likely to have more impact in those consuming low intakes of FVs.

Conflict of Interest Statement

DJM and JES report grants from Abbott Australasia Pty Ltd, Alphapharm Pty Ltd, AstraZeneca, Bristol-Myers Squibb, Eli Lilly Australia, GlaxoSmithKline, Janssen-Cilag, Merck Sharp & Dohme, Novartis Pharmaceuticals, Novo Nordisk Pharmaceuticals, Roche Diagnostics Australia, Sanofi Aventis and Sanofi-synthelabo, during the conduct of the study. RMD received a Primary Growth Partnership grant via the Ministry of Primary Industries in New Zealand with Fonterra Co-operative Group Ltd, outside the submitted work. All other authors have no potential conflicts of interest to report. JMH reports grants from FruitWest, grants from Department of Agriculture and Food WA, outside the submitted work.

REFERENCES

1. Association AP (2013) Diagnostic and statistical manual of mental disorders (DSM-5®). American Psychiatric Pub,

2. Depression (2018) https://www.who.int/news-room/fact-sheets/detail/depression.

3. (ABS) ABoS (2008) National Survey of Mental Health and Wellbeing: Summary of Results, 4326.0, 2007. Australian Bureau of Statistics Canberra

4. Roger W, Inga L, Peter B, Esperanza V-T (2018) The Household, Income and Labour Dynamics in Australia Survey:Selected Findings from Waves 1 to 17. (The 14th Annual Statistical Report of the HILDA Survey)

5. World Health Organization (2017) Depression and other common mental disorders: global health estimates. World Health Organization,

6. Patel V, Chisholm D, Parikh R, Charlson FJ, Degenhardt L, Dua T, Ferrari AJ, Hyman S, Laxminarayan R, Levin C (2016) Addressing the burden of mental, neurological, and substance use disorders: key messages from Disease Control Priorities. The Lancet 387 (10028):1672-1685

7. Mindframe (2019) Australia Suicide data 2018. Australian Bureau of Statistics, Canberra

8. Snyder HR (2013) Major depressive disorder is associated with broad impairments on neuropsychological measures of executive function: a meta-analysis and review. Psychological bulletin 139 (1):81

9. Dhar AK, Barton DA (2016) Depression and the link with cardiovascular disease. Frontiers in psychiatry 7:33

10. Firth J, Marx W, Dash S, Carney R, Teasdale SB, Solmi M, Stubbs B, Schuch FB, Carvalho AF, Jacka F (2019) The effects of dietary improvement on symptoms of depression and anxiety: a meta-analysis of randomized controlled trials. Psychosomatic medicine 81 (3):265

11. Huskisson E, Maggini S, Ruf M (2007) The influence of micronutrients on cognitive function and performance. J Int Med Res 35 (1):1-19. doi:10.1177/147323000703500101

12. Akbaraly TN, Sabia S, Shipley MJ, Batty GD, Kivimaki M (2013) Adherence to healthy dietary guidelines and future depressive symptoms: evidence for sex differentials in the Whitehall II study. Am J Clin Nutr 97 (2):419-427. doi:10.3945/ajcn.112.041582

13. Nanri A, Kimura Y, Matsushita Y, Ohta M, Sato M, Mishima N, Sasaki S, Mizoue T (2010) Dietary patterns and depressive symptoms among Japanese men and women. European journal of clinical nutrition 64 (8):832-839

14. Kuczmarski MF, Cremer Sees A, Hotchkiss L, Cotugna N, Evans MK, Zonderman AB (2010) Higher Healthy Eating Index-2005 scores associated with reduced symptoms of depression in an urban population: findings from the Healthy Aging in Neighborhoods of Diversity Across the Life Span (HANDLS) study. J Am Diet Assoc 110 (3):383-389. doi:10.1016/j.jada.2009.11.025

15. Jacka FN, Cherbuin N, Anstey KJ, Sachdev P, Butterworth P (2015) Western diet is associated with a smaller hippocampus: a longitudinal investigation. BMC medicine 13 (1):215

16. Jacka FN, Cherbuin N, Anstey KJ, Butterworth P (2014) Dietary patterns and depressive symptoms over time: examining the relationships with socioeconomic position, health behaviours and cardiovascular risk. PloS one 9 (1)

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

18. Mihrshahi S, Dobson A, Mishra G (2015) Fruit and vegetable consumption and prevalence and incidence of depressive symptoms in mid-age women: results from the

Australian longitudinal study on women’s health. European journal of clinical nutrition 69 (5):585-591

19. McMartin SE, Jacka FN, Colman I (2013) The association between fruit and vegetable consumption and mental health disorders: evidence from five waves of a national survey of Canadians. Preventive medicine 56 (3-4):225-230

20. Tsai AC, Chang T-L, Chi S-H (2012) Frequent consumption of vegetables predicts lower risk of depression in older Taiwanese–results of a prospective population-based study. Public Health Nutrition 15 (6):1087-1092

21. Woo J, Lynn H, Lau W, Leung J, Lau E, Wong S, Kwok T (2006) Nutrient intake and psychological health in an elderly Chinese population. International Journal of Geriatric Psychiatry: A journal of the psychiatry of late life and allied sciences 21 (11):1036-1043

22. Brookie KL, Best GI, Conner TS (2018) Intake of raw fruits and vegetables is associated with better mental health than intake of processed fruits and vegetables. Frontiers in psychology 9:487

23. Oddy WH, Robinson M, Ambrosini GL, Therese A, de Klerk NH, Beilin LJ, Silburn SR, Zubrick SR, Stanley FJ (2009) The association between dietary patterns and mental health in early adolescence. Preventive medicine 49 (1):39-44

24. Dunstan DW, Zimmet PZ, Welborn TA, Cameron AJ, Shaw J, de Courten M, Jolley D, McCarty DJ (2002) The Australian Diabetes, Obesity and Lifestyle Study (AusDiab)—methods and response rates. Diabetes Research and Clinical Practice 57 (2):119-129. doi:https://doi.org/10.1016/S0168-8227(02)00025-6

25. Ireland P, Jolley D, Giles G, O’Dea K, Powles J, Rutishauser I, Wahlqvist ML, Williams J (1994) Development of the Melbourne FFQ: a food frequency questionnaire for use in an Australian prospective study involving an ethnically diverse cohort. Asia Pac J Clin Nutr 3 (1):19-31

26. Blekkenhorst LC, Hodgson JM, Lewis JR, Devine A, Woodman RJ, Lim WH, Wong G, Zhu K, Bondonno CP, Ward NC (2017) Vegetable and fruit intake and fracture-related hospitalisations: a prospective study of older women. Nutrients 9 (5):511

27. (ABS) ABoS (2014) 4364.0.55.007 - Australian Health Survey: Nutrition First Results - Foods and Nutrients, 2011-12 Australian Bureau of Statistics (ABS)

28. NHMRC (2013) Australian dietary guidelines.

29. Blekkenhorst LC, Bondonno CP, Lewis JR, Devine A, Zhu K, Lim WH, Woodman RJ, Beilin LJ, Prince RL, Hodgson JM (2017) Cruciferous and allium vegetable intakes are inversely associated with 15-year atherosclerotic vascular disease deaths in older adult women. Journal of the American Heart Association 6 (10):1-15

30. Blekkenhorst L, Sim M, Bondonno C, Bondonno N, Ward N, Prince R, Devine A, Lewis J, Hodgson J (2018) Cardiovascular health benefits of specific vegetable types: A narrative review. Nutrients 10 (5):595

31. Quiñones M, Miguel M, Aleixandre A (2013) Beneficial effects of polyphenols on cardiovascular disease. Pharmacological Research 68 (1):125-131. doi:http://dx.doi.org/10.1016/j.phrs.2012.10.018

32. Vazquez-Prieto MA, Miatello RM (2010) Organosulfur compounds and cardiovascular disease. Molecular aspects of medicine 31 (6):540-545

33. Voutilainen S, Nurmi T, Mursu J, Rissanen TH (2006) Carotenoids and cardiovascular health–. The American journal of clinical nutrition 83 (6):1265-1271

34. Weitzberg E, Lundberg JO (2013) Novel aspects of dietary nitrate and human health. Annual review of nutrition 33:129-159

35. Andresen EM, Malmgren JA, Carter WB, Patrick DL (1994) Screening for depression in well older adults: Evaluation of a short form of the CES-D. American journal of preventive medicine 10 (2):77-84

36. Baron EC, Davies T, Lund C (2017) Validation of the 10-item centre for epidemiological studies depression scale (CES-D-10) in Zulu, Xhosa and Afrikaans populations in South Africa. BMC psychiatry 17 (1):6

37. Zhang W, O'Brien N, Forrest JI, Salters KA, Patterson TL, Montaner JS, Hogg RS, Lima VD (2012) Validating a shortened depression scale (10 item CES-D) among HIV-positive people in British Columbia, Canada. PloS one 7 (7):e40793

38. LaChapelle DL, Alfano DP (2005) Revised neurobehavioral scales of the MMPI: Sensitivity and specificity in traumatic brain injury. Applied Neuropsychology 12 (3):143-150

39. Miller W, Anton H, Townson A (2008) Measurement properties of the CESD scale among individuals with spinal cord injury. Spinal cord 46 (4):287

40. ELM Barr DM, PZ Zimmet, KR Polkinghorne, RC Atkins, DW Dunstan, SG Murray, JE Shaw (2006) AusDiab 2005: The Australian Diabetes, Obesity and Lifestyle Study - Tracking the Accelerating Epidemic: Its Causes and Outcomes. International Diabetes Institute, Melbourne, Australia. https://www.baker.edu.au/Assets/Files/AUSDIAB_REPORT_2005.pdf.

41. Dalton M, Cameron AJ, Zimmet PZ, Shaw JE, Jolley D, Dunstan DW, Welborn TA, Committee AS (2003) Waist circumference, waist–hip ratio and body mass index and their correlation with cardiovascular disease risk factors in Australian adults. Journal of internal medicine 254 (6):555-563

42. Backholer K, Spencer E, Gearon E, Magliano DJ, McNaughton SA, Shaw JE, Peeters A (2015) The association between socio-economic position and diet quality in Australian adults. Public Health Nutrition 19 (3):477-485. doi:10.1017/S1368980015001470

43. Cameron AJ, Zimmet PZ, Dunstan DW, Dalton M, Shaw JE, Welborn TA, Owen N, Salmon J, Jolley D (2003) Overweight and obesity in Australia: the 1999–2000 Australian diabetes, obesity and lifestyle study (AusDiab). Medical journal of Australia 178 (9):427-432

44. Armstrong T, Bauman AE, Davies J (2000) Physical activity patterns of Australian adults: results of the 1999 National Physical Activity Survey. Australian Institute of Health and Welfare,

45. Statistics ABo (2011) Socio-economic indexes for areas (SEIFA) Australia: Postal areas, index of relative socio-economic advantage and disadvantage. Author Canberra,

46. Diabetes A, Dunstan DW (2001) Diabesity & Associated Disorders in Australia-2000: The Accelerating Epidemic. International Diabetes Institute,

47. McNaughton SA, Ball K, Crawford D, Mishra GD (2008) An index of diet and eating patterns is a valid measure of diet quality in an Australian population. The Journal of nutrition 138 (1):86-93

48. AGHE (2015) Australian Guide To Healthy Eating | Eat For Health. [online].

49. IBM C (2017) IBM SPSS Statistics for Windows, Version Q3 25.0. Armonk, NY: IBM Corp

50. Team RC (2019) R: A language and environment for statistical computing (Version 3.0. 2)[Computer software]. Vienna, Austria: R Foundation for Statistical Computing.

51. Harrell Jr F (2019) rms: Regression Modeling Strategies. R package version 5.1–3. 1. 2019.

52. Saghafian F, Malmir H, Saneei P, Milajerdi A, Larijani B, Esmaillzadeh A (2018) Fruit and vegetable consumption and risk of depression: accumulative evidence from an updated systematic review and meta-analysis of epidemiological studies. British Journal of Nutrition 119 (10):1087-1101

53. Payne ME, Jamerson BD, Potocky CF, Ashley-Koch AE, Speer MC, Steffens DC (2009) Natural food folate and late-life depression. Journal of nutrition for the elderly 28 (4):348-358

54. Park J-Y, You J-S, Chang K-J (2010) Dietary taurine intake, nutrients intake, dietary habits and life stress by depression in Korean female college students: a case-control study. Journal of biomedical science 17 (S1):S40

55. Tolmunen T, Voutilainen S, Hintikka J, Rissanen T, Tanskanen A, Viinamäki H, Kaplan GA, Salonen JT (2003) Dietary folate and depressive symptoms are associated in middle-aged Finnish men. The Journal of nutrition 133 (10):3233-3236

56. Kodydková J, Vávrová L, Zeman M, Jirák R, Macášek J, Staňková B, Tvrzická E, Žák A (2009) Antioxidative enzymes and increased oxidative stress in depressive women. Clinical biochemistry 42 (13-14):1368-1374

57. Maes M, Mihaylova I, Kubera M, Uytterhoeven M, Vrydags N, Bosmans E (2009) Increased 8-hydroxy-deoxyguanosine, a marker of oxidative damage to DNA, in major depression and myalgic encephalomyelitis/chronic fatigue syndrome. Neuroendocrinology Letters 30 (6):715

58. Rao TS, Asha M, Ramesh B, Rao KJ (2008) Understanding nutrition, depression and mental illnesses. Indian journal of psychiatry 50 (2):77

59. Bodnar LM, Wisner KL (2005) Nutrition and depression: implications for improving mental health among childbearing-aged women. Biological psychiatry 58 (9):679-685

60. Forlenza MJ, Miller GE (2006) Increased serum levels of 8-hydroxy-2′-deoxyguanosine in clinical depression. Psychosomatic medicine 68 (1):1-7

61. Black CN, Penninx BW, Bot M, Odegaard AO, Gross MD, Matthews KA, Jacobs D (2016) Oxidative stress, anti-oxidants and the cross-sectional and longitudinal association with depressive symptoms: results from the CARDIA study. Translational psychiatry 6 (2):e743-e743

62. Howren MB, Lamkin DM, Suls J (2009) Associations of depression with C-reactive protein, IL-1, and IL-6: a meta-analysis. Psychosomatic medicine 71 (2):171-186

63. Raubenheimer K, Bondonno C, Blekkenhorst L, Wagner K-H, Peake JM, Neubauer O (2019) Effects of dietary nitrate on inflammation and immune function, and implications for cardiovascular health. Nutrition Reviews 77 (8):584-599

64. Ford DE, Erlinger TP (2004) Depression and C-reactive protein in US adults: data from the Third National Health and Nutrition Examination Survey. Archives of internal medicine 164 (9):1010-1014

65. Rooney C, McKinley MC, Woodside JV (2013) The potential role of fruit and vegetables in aspects of psychological well-being: a review of the literature and future directions. Proceedings of the Nutrition Society 72 (4):420-432

66. Black CN, Bot M, Scheffer PG, Cuijpers P, Penninx BW (2015) Is depression associated with increased oxidative stress? A systematic review and meta-analysis. Psychoneuroendocrinology 51:164-175

67. Frusciante L, Carli P, Ercolano MR, Pernice R, Di Matteo A, Fogliano V, Pellegrini N (2007) Antioxidant nutritional quality of tomato. Molecular nutrition & food research 51 (5):609-617

68. Sarandol A, Sarandol E, Eker SS, Erdinc S, Vatansever E, Kirli S (2007) Major depressive disorder is accompanied with oxidative stress: short-term antidepressant treatment does not alter oxidative–antioxidative systems. Human Psychopharmacology: Clinical and Experimental 22 (2):67-73

69. Maiani G, Periago Castón MJ, Catasta G, Toti E, Cambrodón IG, Bysted A, Granado-Lorencio F, Olmedilla-Alonso B, Knuthsen P, Valoti M (2009) Carotenoids: actual knowledge on food sources, intakes, stability and bioavailability and their protective role in humans. Molecular nutrition & food research 53 (S2):S194-S218

70. Kaulmann A, Bohn T (2014) Carotenoids, inflammation, and oxidative stress—implications of cellular signaling pathways and relation to chronic disease prevention. Nutrition research 34 (11):907-929

71. Parletta N, Zarnowiecki D, Cho J, Wilson A, Bogomolova S, Villani A, Itsiopoulos C, Niyonsenga T, Blunden S, Meyer B (2019) A Mediterranean-style dietary intervention supplemented with fish oil improves diet quality and mental health in people with depression: A randomized controlled trial (HELFIMED). Nutritional neuroscience 22 (7):474-487

72. Payne ME, Steck SE, George RR, Steffens DC (2012) Fruit, vegetable, and antioxidant intakes are lower in older adults with depression. Journal of the Academy of Nutrition and Dietetics 112 (12):2022-2027

73. Organization WH (2012) Depression: A Global Crisis. World Mental Health Day, October 10 2012. World Federation for Mental Health, Occoquan, Va, USA

74. Statistics ABo (2018) 4364.0. 55.001-National Health Survey: first results, 2017–18. Australian Government Canberra, ACT,

75. Akbaraly TN, Brunner EJ, Ferrie JE, Marmot MG, Kivimaki M, Singh-Manoux A (2009) Dietary pattern and depressive symptoms in middle age. The British Journal of Psychiatry 195 (5):408-413

TABLES

Table 1. Baseline characteristics by quartiles of habitual fruit and vegetable intake among Australian men and women

		Quartiles of habitual/average FV intake			
Baseline characteristics	**All participants**	**Q1 (0-273) g/day**	**Q2 (274-361) g/day**	**Q3 (362-464) g/day**	**Q4 (≥465) g/day**
	n=4,105	**n=1,027**	**n=1,026**	**n=1,027**	**n=1,025**
Age (years)	49 ± 11	46 ± 11	49 ± 11	49 ± 11	51 ± 11
Sex, n (%) - female	2,285 (55.7)	561 (54.6)	600 (58.5)	599 (58.3)	525 (51.2)
BMI (kg/m^2), mean ± SD	27 ± 5	26 ± 5	26 ± 5	27 ± 5	27 ± 5
Energy intake (kcal/day)	2,022 ± 666	1,883 ± 654	1,946 ± 623	2,007 ± 637	2,253 ± 690
Physical activity, n (%)					
Sedentary	630 (15.3)	209 (20.4)	151 (14.7)	158 (15.4)	112 (10.9)
Insufficient (<150min/w)	1,263 (30.8)	344 (33.5)	335 (32.7)	321 (31.3)	263 (25.7)
Sufficient (>150min/w)	2,212 (53.9)	474 (46.2)	540 (52.6)	548 (53.4)	650 (63.4)
Smoking status, n (%)					
Current	438 (10.7)	183 (17.8)	119 (11.6)	81 (7.9)	55 (5.4)
Ex-smoker	1,180 (28.7)	268 (26.1)	299 (29.1)	310 (30.2)	303 (29.6)
Non-smoker	2,487 (60.6)	576 (56.1)	608 (59.3)	636 (61.9)	667 (65.1)
SEIFA, mean ± SD	1,029 ± 80	1,029 ± 82	1,028 ± 80	1,031 ± 75	1,029 ± 84
Relationship status, n (%)					
Married	3,180 (77.5)	760 (74.9)	812 (79.1)	794 (77.3)	805 (78.5)
De facto	183 (4.5)	48 (4.7)	52 (5.1)	42 (4.1)	41 (4.0)
Separated	80 (1.9)	22 (2.1)	18 (1.8)	19 (1.9)	21 (2.0)
Divorced	233 (5.7)	60 (5.8)	49 (4.8)	67 (6.5)	57 (5.6)
Widowed	103 (2.5)	18 (1.8)	25 (2.4)	31 (3.0)	30 (2.9)
Single	325 (7.9)	110 (10.7)	70 (6.8)	74 (7.2)	71 (6.9)
Level of education, n (%)					
Never to some high school	1,355 (33.0)	353 (34.4)	355 (34.6)	328 (31.9)	319 (31.1)
Completed university or equivalent	2,750 (67.0)	674 (65.6)	671 (65.4)	699 (68.1)	706 (68.9)
Prevalent CVD, n (%)	168 (4.1)	39 (3.8)	37 (3.6)	47 (4.6)	45 (4.4)
Diabetes, n (%)					

Known Diabetes Mellitus	97 (2.4)	21 (2.0)	22 (2.1)	35 (3.4)	19 (1.9)
Impaired fasting glucose	233 (5.7)	55 (5.4)	71 (6.9)	47 (4.6)	60 (5.9)
Impaired glucose tolerance	391 (9.5)	100 (9.7)	100 (9.7)	93 (9.1)	98 (9.6)
New Diabetes Mellitus	110 (2.7)	22 (2.1)	27 (2.6)	28 (2.7)	33 (3.2)
Normal glucose levels	3,274 (78.8)	829 (80.7)	806 (78.6)	824 (80.2)	815 (79.5)
CESD-10 score, mean ± SD	4.0 ± 4.4	4.7 ± 4.8	4.0 ± 4.3	3.9 ± 4.2	3.7 ± 4.2
Any depressive symptoms (CESD-10 ≥10), n (%)	425 (10.4%)	133 (13.0)	105 (10.2)	102 (9.9)	85 (8.3)

Data is shown as mean ± SD (standard deviation), or number (%).

BMI, Body Mass Index; SEIFA, Socio-Economic Index For Areas); CVD, Cardiovascular Disease; CESD-10, Centre for Epidemiology Studies Short Depression Scale – 10 item version; FV, Fruit and Vegetable.

Table 2. Odds ratio for depressive symptoms at 12 years by quartiles of the habitual FV intake in men and women

	Quartiles of the habitual intake of FV intake (n=4,105)			
Depressive symptoms (CESD-10 ≥10; n=425)	**Q1 n=1,027**	**Q2 n=1,026**	**Q3 n=1,027**	**Q4 n=1,025**
	Fruit and vegetables (g/day)			
Median (IQR)	223 (187 – 249)	317 (295 – 339)	409 (383 – 433)	547 (502 – 629)
Model 1[a]	Reference	0.76 (0.65, 0.89)	0.77 (0.62, 0.96)	0.72 (0.55, 0.95)
Model 2[b]	Reference	0.80 (0.69, 0.95)	0.83 (0.66, 1.03)	0.79 (0.59, 1.05)
	Fruit (g/day)			
Median (IQR)	80 (63 – 98)	149 (132 – 168)	227 (206 – 249)	349 (306 – 406)
Model 1[a]	Reference	0.73 (0.59, 0.90)	0.72 (0.58, 0.91)	0.72 (0.55, 0.94)
Model 2[b]	Reference	0.81 (0.65, 1.00)	0.83 (0.65, 1.05)	0.84 (0.63, 1.11)
	Vegetables (g/day)			
Median (IQR)	105 (84 – 118)	148 (138 – 157)	188 (177 – 199)	249 (228 – 280)
Model 1[a]	Reference	0.80 (0.71, 0.91)	0.82 (0.67, 1.02)	0.78 (0.60, 1.03)
Model 2[b]	Reference	0.82 (0.72, 0.94)	0.82 (0.66, 1.03)	0.77 (0.58, 1.02)

Odds ratios (OR) and 95% CI (95% Confidence Intervals) for depressive symptoms at 12 years, obtained from restricted cubic splines based on logistic regression models.

[a]Model 1: minimally adjusted for age and sex

[b]Model 2: multivariable adjusted for age, sex, BMI (body mass index), energy intake, relationship status, physical activity, level of education, SEIFA (Socio-economic index for areas), smoking status, diabetes and self-reported history of cardiovascular disease

Total n=4,105 (No depressive symptoms: 3,680)

CESD-10, Centre for Epidemiology Studies Short Depression Scale; FV, Fruit and Vegetables.

Table 3. Odds ratio for depressive symptoms at 12 years by quartiles of the habitual intake of types of fruit and vegetables in men and women

	Quartiles of the habitual intake of types of fruit and vegetables (n=4,105)			
Depressive symptoms	**Q1**	**Q2**	**Q3**	**Q4**
(CESD-10 ≥10; n=425)	**n=1,027**	**n=1,026**	**n=1,027**	**n=1,025**
		Bananas (g/day)		
Median (IQR)	8 (4 – 11)	22 (18 – 26)	39 (34 – 44)	68 (58 – 83)
Model 1[a]	Reference	0.92 (0.74, 1.13)	0.77 (0.61, 0.97)	0.65 (0.49, 0.85)
Model 2[b]	Reference	0.96 (0.77, 1.13)	0.87 (0.68, 1.10)	0.75 (0.56, 1.00)
		Oranges and other citrus (g/day)		
Median (IQR)	5 (3 – 8)	17 (13 – 21)	36 (31 – 43)	80 (63 – 108)
Model 1[a]	Reference	0.95 (0.77, 1.18)	0.84 (0.66 ,1.06)	0.76 (0.58, 1.01)
Model 2[b]	Reference	1.04 (0.84, 1.30)	0.96 (0.75, 1.23)	0.89 (0.67, 1.19)
		Apples and pears (g/day)		
Median (IQR)	15 (8 – 20)	38 (32 – 45)	71 (62 – 82)	130 (110 – 168)
Model 1[a]	Reference	0.86 (0.70, 1.06)	0.81 (0.65, 1.01)	0.75 (0.58, 0.99)
Model 2[b]	Reference	0.93 (0.75, 1.11)	0.90 (0.72, 1.14)	0.86 (0.65, 1.14)
		Cruciferous vegetables (g/day)		
Median (IQR)	9 (6 – 12)	18 (16 – 20)	26 (24 – 29)	41 (36 – 51)
Model 1[a]	Reference	0.92 (0.77, 1.10)	0.87 (0.71, 1.07)	0.87 (0.66, 1.14)
Model 2[b]	Reference	0.95 (0.79, 1.13)	0.88 (0.71, 1.09)	0.85 (0.64, 1.12)
		Allium vegetables (g/day)		
Median (IQR)	2 (1 – 3)	5 (4 – 5)	8 (7 – 8)	12 (11 – 15)
Model 1[a]	Reference	0.88 (0.72, 1.07)	0.87 (0.70, 1.08)	0.85 (0.65, 1.12)
Model 2[b]	Reference	0.93 (0.76, 1.14)	0.94 (0.75, 1.17)	0.91 (0.69 ,1.20)
		Yellow/orange/red vegetables (g/day)		
Median (IQR)	25 (19 – 29)	39 (36 – 42)	51 (48 – 55)	71 (64 – 83)
Model 1[a]	Reference	0.85 (0.73, 0.99)	0.74 (0.60, 0.91)	0.67 (0.51, 0.88)
Model 2[b]	Reference	0.89 (0.76, 1.05)	0.76 (0.61, 0.95)	0.69 (0.52, 0.92)
		Leafy green vegetables (g/day)		
Median (IQR)	7 (5 – 8)	12 (11 – 13)	17 (16 – 19)	26 (23 – 30)
Model 1[a]	Reference	0.83 (0.71, 0.97)	0.68 (0.55, 0.85)	0.56 (0.42, 0.73)
Model 2[b]	Reference	0.89 (0.76, 1.05)	0.75 (0.60, 0.93)	0.62 (0.47, 0.82)

		Legumes (g/day)		
Median (IQR)	13 (10 – 16)	23 (21 – 25)	32 (30 – 35)	47 (42 – 56)
Model 1[a]	Reference	0.84 (0.71, 0.99)	0.92 (0.75, 1.14)	0.97 (0.74, 1.26)
Model 2[b]	Reference	0.84 (0.71, 1.00)	0.91 (0.73, 1.12)	0.92 (0.70, 1.21)

Odds ratios (OR) and 95% CI (95% Confidence Intervals) for depressive symptoms at 12 years, obtained from restricted cubic splines based on logistic regression models.

[a]Model 1: minimally adjusted for age and sex

[b]Model 2: multivariable adjusted for age, sex, BMI (body mass index), energy intake, relationship status, physical activity, level of education, SEIFA (Socio-economic index for areas), smoking status, diabetes and self-reported history of cardiovascular disease

Total n=4,105 (No depressive symptoms: 3,680)

CESD-10, Centre for Epidemiology Studies Short Depression Scale; FV, Fruit and Vegetables.

Table 4. Odds ratio for depressive symptoms at 12 years by habitual vegetable diversity in men and women

	Habitual vegetable diversity (number of types of vegetables consumed per day)[c]			
Depressive symptoms (CESD-10 ≥10; n=425)	**≤3** **1,041 (25.0%)**	**4** **1,173 (28%)**	**5** **1,017 (25.0%)**	**≥6** **874 (22%)**
Model 1[a]	Reference	0.71 (0.59, 0.85)	0.54 (0.40, 0.71)	0.51 (0.38, 0.70)
Model 2[b]	Reference	0.76 (0.63, 0.92)	0.58 (0.43, 0.77)	0.59 (0.43, 0.82)

Odds ratios (OR) and 95% CI (95% Confidence Intervals) for depressive symptoms at 12 years, obtained from restricted cubic splines based on logistic regression models.

[a]Model 1: minimally adjusted for age and sex

[b]Model 2: multivariable adjusted for age, sex, BMI (body mass index), energy intake, relationship status, physical activity, level of education, SEIFA (Socio-economic index for areas), smoking status, diabetes and self-reported history of cardiovascular disease

Total n=4,105 (No depressive symptoms: n=3,680)

[c]Values represent a range of number of different vegetables consumed in a day, based on the average of at least 2 measures (≤3, 4, 5, ≥6)

CESD-10, Centre for Epidemiology Studies Short Depression Scale.

LEGENDS FOR FIGURES

Fig. 1 Association between habitual FV intake and depressive symptoms at 12 years. Odds ratios from logistic regression models with restricted cubic spline curves describing the association between the habitual intake of: a) Fruit and vegetable (g/day); b) Fruit (g/ day) and; c) Vegetable (g/ day) intake over 12 years, and depressive symptoms at 12 years (vertical axis). Odds ratios are based on models adjusting for age, sex, BMI, energy intake, relationship status, physical activity, level of education, SEIFA (Socio-economic index for areas), smoking status, diabetes status, and self-reported history of cardiovascular disease, and are comparing the specific level of intake (horizontal axis) to the median (IQR) intake for participants in the lowest intake quartile (fruit and vegetable: 223 [187 – 249] g/day; fruit: 80 [63 – 98] g/day; vegetable: 105 [84 – 118] g/day)

Fig. 2 Association between habitual vegetable diversity and depressive symptoms at 12 years. Odds ratios from logistic regression models with restricted cubic spline curves describing the association between habitual vegetables diversity (horizontal axis), and depressive symptoms at 12 years (vertical axis) ($p<0.05$). Odds ratios are based on models adjusting for age, sex, BMI, energy intake, relationship status, physical activity, level of education, SEIFA (Socio-economic index for areas), smoking status, diabetes status, and self-reported history of cardiovascular disease