Title: Diet quality and depressive symptoms. Assessing the direction of the association in a population-based cohort study.

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ABSTRACT

Background: Emerging evidence links a poor diet with mental ill-health although the direction of this association is unclear. The aim was to examine the bidirectional prospective relationships between core (and non-core food consumption, and symptoms of depression.

Methods: Depressive symptoms (Mental Health Index-5, MHI-5), current/prior depression and consumption of core (recommended food groups) and non-core (discretionary) foods were assessed in the population-based 2013 and 2017 Household Income and Labour Dynamics in Australia cohort study. Three cross-lagged linear models assessed associations between all three baseline variables in 2013, alternating 2017 variables as outcomes.

Results: In the population (n=10,003; 48.3% women; 48.5[15.7] years), core food score in 2013 was associated with MHI-5 (β:0.102, 95%CI: 0.010,0.193) in 2017, while the non-core food score was not (β:-0.030, 95%CI:-0.099,0.160). Depressive symptom score in 2013 was not associated with either food score in 2017. Current/prior diagnosis of depression in 2013 was associated with core (β:-0.198, 95%CI:-0.329,-0.067) but not non-core (β:-0.036, 95%CI: -0.151,0.080) food score in 2017.

Limitations: Results may not be generalizable to the whole population due to some selection bias, self-report depression diagnosis may have led to misclassification of previous mental illness, and core and non-core food scores are not validated measures of diet quality.

Conclusions: There is a prospective association between core food consumption and depressive symptoms. This association is of small magnitude, and we cannot discount insufficient core food consumption reflecting an effect of prior mental illness. Our results suggest that, for depression, public health focus should be on improving core food intake.

Keywords: diet quality, mental health, depression, prospective study

HIGHLIGHTS

- Higher core food score was prospectively associated with fewer depressive symptoms
- Non-core food score was not prospectively associated with depressive symptoms
- Depressive symptom score was not prospectively associated with either food score
- Depression diagnosis was prospectively associated with lower core food score
- The association between diet quality and depressive symptoms is not bidirectional

INTRODUCTION

Several meta-analyses have reported that adherence to a high-quality diet, usually defined as a diet high in core foods from the recommended food groups such as fruits, vegetables, whole grains, fish, low fat meats and dairy, legumes and nuts, is prospectively associated with a lower risk of depression (Li et al., 2017; Molendijk et al., 2018a). However, an association between a low-quality diet, often defined as high in non-core, discretionary foods such as takeaway foods, confectionary, processed meat and refined grains, and depression risk has not been established (Li et al., 2017; Molendijk et al., 2018a). While the understanding of which biological mechanisms mediate associations between diet and mental health are limited, hypotheses include inflammatory and oxidative stress pathways (Jacka, 2017). A limitation of prior studies is the possibility of diet quality being a consequence of depression rather than a risk factor, or simply a concurrent aspect of the early stages of a depressive episode rather than a causal factor for depression (Molendijk et al., 2018a). Having a previous episode of depressive disorder and not achieving full remission (i.e., ongoing subthreshold symptoms) increases the risk of subsequent depressive episode (Karsten et al., 2011). Some studies control for this issue by excluding those with baseline depression, or a history of depression from analysis (Akbaraly et al., 2009; Sanchez-Villegas et al., 2009; Skarupski et al., 2013). However, this still does not fully account for the fact that subclinical symptoms of mental illness at baseline may be the start of a new depressive incidence (Karsten et al., 2011) and may influence baseline diet quality. One meta-analysis analyzed a subset of studies that controlled for baseline symptoms of depression (3 of 24 studies), and found no association between diet quality and depression risk (Molendijk et al., 2018a). These studies were of mid-aged and older women, which limits generalizability, but reverse causality appears possible, if not likely (Chocano-Bedoya et al., 2013; Lai et al., 2016; Rienks et al., 2012). In contrast, another study reported a significant association between a

'prudent' diet pattern and depressive symptoms in the group aged over 60 years, but not younger cohorts, after adjusting for baseline depressive symptoms (Jacka et al., 2014). Clear inconsistencies in establishing the diet-depression link exist, and few studies in adults have empirically tested the reverse casualty hypothesis; that poor diet quality is a consequence of depressive symptoms.

The current study aims to examine the bidirectional relationship between core and non-core food consumption and symptoms of depression in an adult population-based sample while adjusting for a wide range of potential confounders. Three hypotheses were tested: (i) More varied and frequent consumption of core foods and less frequent consumption of non-core foods in 2013 will be associated with fewer symptoms of depression in 2017, after controlling for depression symptom score in 2013, (ii) A higher depression symptom score in 2013 will be associated with less frequent consumption of core foods in 2017, after controlling for core food score in 2013, and (iii) A higher depression symptom score in 2013 will be associated with more frequent consumption of non-core food score in 2017, after controlling for non-core food score in 2013.

METHODS

Study design

The study analyzed two waves (2013 and 2017) of the Household Income and Labour Dynamics in Australia (HILDA) study. HILDA is an ongoing, broad Australian household-based panel study which started in 2001 and surveys participants on a yearly basis. It collects data on economic, labor market and family dynamics, including a range of other topics such as education, health and wellbeing, though not every topic is included every year. The majority of interviews are conducted face-to-face, or in a small number of cases, on phone where necessary. Respondents also complete a questionnaire that contains more sensitive

questions, such as those related to mental health. The HILDA Project was initiated and is funded by the Australian Government Department of Social Services (DSS) and is managed by the Melbourne Institute of Applied Economic and Social Research. The findings and views reported in this paper, however, are those of the author and should not be attributed to either DSS or the Melbourne Institute. The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008. All procedures involving human subjects/patients were approved by the Human Ethics Research Committee of The University of Melbourne (ID: 1647030). Written informed consent was obtained from all participants. Further details on the survey and methodology can be found elsewhere (Summerfield et al., 2015).

The response rate for HILDA in 2013 was 69.2% (n=17,501) and 64.5% (n=17,784) in 2017. Participants were not eligible for inclusion if aged under 18 years (n=863), and only those with complete data for all covariates were included in analysis, see participant flow chart in Figure 1. A total of 10,003 (66.3% of eligible) had complete data for all study variables in 2013 and outcome variables in 2017.

Mental health symptoms

The five-item Mental Health Inventory (MHI-5) is a 5 item questionnaire that can be used to screen for depression in primary care (Cuijpers et al., 2009). A six-point Likert scale was used to report frequency of five symptom statements, ranging from ‘none of the time’ to ‘all of the time’. Raw scores range from 5 to 35 and are standardized by linear transformation to a scale ranging between 0 and 100, with higher scores indicating better mental health (Cuijpers et al., 2009). Good internal consistency has been demonstrated and a cut-point of ≤54 has

shown acceptable ability to detect DSM-III-R diagnosed depression and dysthymia (sensitivity 63%, specificity 96%) (Cuijpers et al., 2009).

Diet quality: core and non-core food score

Nine items assessing the frequency of consuming nutrient dense foods (fruits, vegetables, legumes/pulses, poultry, red meat, fish, breads and cereals, pasta, rice and corn products), two items for the average number of serves of fruits and vegetables eaten per day, one item for usual type of milk consumed, and one item on frequency of adding salt to meals was used to construct a core food score (Appendix 4). For the items asking about consumption of breads, cereals, pasta, rice and corn products, fish and legumes the participant had to consume the food once or more per week to score a point. For poultry and red meat there was an upper limit, and a point was only awarded if it was consumed between one and four times per week. The maximum score for core food was 19 points and a higher score indicates a greater dietary variety and adherence to Australian dietary recommendations (National Health and Medical Research Council, 2013). A non-core food score was constructed based on five frequency items for discretionary foods (confectionary and ice-cream, biscuits, cakes and desserts, processed meat products, snack foods, fried potato), and greater frequency in purchasing food from an outlet (restaurant, café, fast food outlet). These foods are often nutrient poor and high in energy (kilojoules), saturated fat, added sugar and/or salt. The maximum score for non-core foods was 12 points and a higher score indicates more frequent consumption of discretionary food items and eating out (Appendix 4).

Baseline (2013) covariates

Demographics and socioeconomic status. Participants self-reported age, sex, postcode, marital status, education, income, and work-status. Postcode was used to determine Socioeconomic Index for Areas (SEIFA) decile using the 2001 Index of relative

socioeconomic advantage/disadvantage (Australian Bureau of Statistics, 2011). Income was calculated as the product of positive less negative gross regular household income in the last financial year. Marital status was categorized as 'partnered' or 'non-partnered'. Education was categorized as 'low', 'intermediate' or 'high'. Work status was categorized as 'daytime work', 'night-time work', 'not in workforce' or 'unemployed'. A detailed description of all study covariates can be found in Appendix 1.

Chronic disease and body mass index: Participants self-reported diagnosis of one or more of nine chronic conditions, which was analysed as a dichtomous variable ('yes'/'no'). Height in centimeters or feet/inches and weight in kilograms, stone/pounds were self-reported to calculate body mass index (BMI, kg/m^2), which was categorised into <18.5 kg/m^2, 18.5-24.9 kg/m^2, 25.0-29.9 $kg/m^{2,}$ and ≥ 30 kg/m^2.

Health behaviours. Cigarette smoking was categorised as 'never smoked', 'previous smoker' and 'current smoker' based on a single item. High risk alcohol use was categorised as 'yes' if participants reported drinking alcohol five days per week or more. Physical activity during the previous week was measured using the International Physical Activity Questionnaire - Short Form (IPAQ-SF).(Bauman et al., 2009) Standard IPAQ-SF scoring procedures were used to subsequently classify participants' physical activity as 'low', 'moderate' or 'high'(Bauman et al., 2009).

A dichotomous variable for insomnia symptoms was created, defined as reporting both difficulty initiating or maintaining sleep and poor subjective sleep quality (Biddle et al., 2019). Sleep duration was classified as 'Meeting recommendations', 'Shorter sleep' or 'Longer sleep'(Hirshkowitz et al.). Sleep duration was calculated separately for the employed and unemployed participants, and included daytime sleep/naps.

Psycho-social factors. The HILDA survey assesses the occurrence of 21 stressful life events in the 12 months preceding the survey. If participants reported experiencing any of these events, they were categorised as 'yes' for the dichotomous 'stressful events in the last 12 months' variable. Loneliness was measured using Flood's Index of Social Support with a total score ranging from -30 to +30, with a lower score indicating greater loneliness (Flood, 2005). Satisfaction with current weight was categorised as 'Satisfied', 'Neutral' and 'Dissatisfied'. Participants self-reported ever receiving a diagnosis of depression and or anxiety using a single-item in 2013, and this variable was dichotomised as 'yes' or 'no'.

Statistical analysis

Descriptive statistics have been reported as mean (SD) or count (%). Comparisons between those with and without symptoms of depression at baseline as assessed by the MHI5 symptom cut-off of ≤54 points to indicate likely diagnosable depression, and between the included versus excluded responders were conducted using t-tests and chi-square tests ($p<0.05$). To determine which stressful life events to include in analysis, the 21 stressful life events were individually tested in a linear regression model and included in the group variable 'stressful life events' if they were associated with both the exposure and outcome. Stressful life events were conservatively included in the categorical variable if the significance level was <0.25 in the univariate analysis (data not shown).

A cross-lagged linear regression analysis was conducted to assess the bidirectional relationship between symptoms of depression, core food and non-core food scores by alternating which variable was the outcome, while adjusting for the baseline value of the outcome. Residual plots indicated that assumptions of normality of residuals and linearity were met. Three models (a, b, c) were examined for each of the three outcomes. Model 'a' only included the independent variables in 2013 and the 2017 value of the outcome (i.e. for

MHI-5 in 2017 as the outcome, covariates were core food score, non-core food score and MHI-5 score in 2013). Model 'b' included all variables from the first model and the fixed baseline (2013) covariates of age, sex, marital status, work status, chronic disease status, BMI category, smoking status, alcohol use, insomnia symptoms, sleep duration and physical activity. Model 'c' included all the variables from model 'b' plus the psycho-social variables: loneliness, weight satisfaction, stressful life events (≤12 months prior to 2013 survey), and self-reported prior or current diagnosed depression or anxiety at baseline. Interaction between self-reported diagnosis of depression and anxiety, and core and non-core food scores were performed in the full model c predicting 2017 MHI-5 score. After entering the full model 'c' for each outcome, covariates which had a significance level of >0.25 were excluded from the models to avoid overfitting, and a log-likelihood test was completed to ensure the removal of covariates did not significantly change the fit of the model ($p>0.05$) or change the point estimates for other covariates by >10%. A sensitivity analysis exploring was conducted to explore how using categorical dependent (2017) and independent (2013) variables influenced findings. Two different MHI5 cut-points were used to indicate 'depression' (≤46 or ≤54 points) vs. 'no depression' (>46 or >54 points) in 2013 and 2017 due to different levels of sensitivity and specificity associated with these cut-points (Cuijpers et al., 2009). The core and non-core food scores were categorized as 'higher (Q4)' or 'lower (Q1-3)' using quartile scores. These analyses were conducted using logistic regression and using model C. All analyses were conducted using Stata 15.0 (StataCorp Texas, USA) and results are presented as beta coefficients (β) or odds ratios (OR) and 95% confidence intervals. A p-value of $p<0.05$ was considered significant.

RESULTS

Sample description

Characteristics of the sample are described in Table 1. The overall sample (n=10,003) had similar numbers of men (51.7%) and women (48.3%) and participants had a mean age of 48.6 years (SD=15.7) at baseline. Compared to those without a likely diagnosis, these participants differed in the distribution of all variables except frequency of drinking alcohol (Table 1). Those excluded from analysis due to missing data differed with respect to several characteristics, compared to those included. Key differences included higher mean age and a lower MHI5 score, as well as a greater likelihood of being female, non-partnered, having lower education, not being in the workforce, and having a chronic disease or current/past diagnosis of depression or anxiety (Appendix 4).

Symptoms of depression in 2017 (Table 2: Models a and b, and Table 3: Model c)

Higher core food score in 2013 was associated with fewer symptoms of depression at follow-up, which corresponds with a higher score on the MHI5- scale in the basic model (Model a, β:0.302, 95%CI: 0.210, 0.393) and in the fully adjusted model (Model c,β:0.102, 95%CI: 0.008, 0.196). A higher non-core food score in 2013 was not associated with symptoms of depression in 2017 (Model a, β:-0.009, 95%CI: -0.143, 0.125). A previous or current diagnosis of depression or anxiety was associated with MHI-5 score in 2017 (Model c, β:-4.278, 95%CI: -5.251, -3.305). There was no interaction between previous or current diagnosis and (i) core food score (β:0.050, 95%CI: -0.197, 0.296) or (ii) non-core food score (β:0.343, 95%CI: -0.050, 0.736) (data not shown in table).

Core and non-core food scores in 2017 (Table 2: Models a and b, Table 3: Model c)

The association between symptoms of depression in 2013 and core food consumption in 2017 was significant in Model a (β:0.005, 95%CI: 0.003, 0.007), but not in the adjusted Models (Model c, β:-0.001, 95%CI: -0.003, 0.002). There was also no association between symptoms of depression in 2013 and non-core food consumption in 2017 (Model a, β:-0.001, 95%CI: -0.003, 0.001). While symptoms of depression in 2013 were not associated with core food consumption in 2017, a current or previous diagnosis of depression or anxiety reported in 2013 was associated with a lower core (Model c, β:-0.198, 95%CI: -0.329, -0.067) but not non-core food (Model c, β:-0.036, 95%CI: -0.151, 0.080) score in 2017.

Sensitivity analysis

The ≤54 and ≤46 point cut-points indicated a prevalence of 'depression' of 11.9% and 6.8% respectively in the study population. When using the ≤54 point cut-point: 1) those in the 'higher' versus 'lower' core food consumption group in 2013 had significantly greater odds of 'no depression' in 2017, whereas there was no association between 'higher' non-core food consumption and 'no depression', and 2) there was no association between those categorised as having 'no depression' in 2013 and 'higher' core or non-core food consumption in 2017. When using the ≤46 point cut-point: 1) there was no association between 'higher' core or non-core food consumption in 2013 and 'no depression' in 2017, and 2) those categorised as having 'no depression' in 2013 had significantly greater odds of having 'higher' core food consumption in 2017, but there was no association between 'no depression' and ' higher' non-core food consumption in 2017.

DISCUSSION

This study sought to examine the bidirectional relationship between core and non-core food consumption and symptoms of depression in a population-based sample. While higher core food score, but not non-core food score, had a small but significant prospective association with lower depressive symptom score, depressive symptom score did not have a prospective association with core or non-core food score. Overall, these findings are in agreement with two recent meta-analyses (Li et al., 2017; Molendijk et al., 2018a) but in disagreement with a sub-analysis done within one of these meta-analyses, where no statistically significant prospective association between diet quality and the odds of depression incidence was found when controlling for baseline symptoms of depression (Molendijk et al., 2018a). However, the latter study assessed risk of a depression diagnosis, not change in depressive symptom score and results are not directly comparable.

While depression symptom score did not have a significant prospective association with diet quality, the current study did find that a current or previous diagnosis of depression or anxiety reported in 2013 was significantly associated with a lower core food score in 2017. This has to the best of our knowledge not been reported previously and suggests we cannot rule out the possibility of reverse causality in the association between diet and depression. The discrepancy in the associations between self-reported diagnosis of depression and core food score, and depressive symptom score and core food score may be due to the fact that the MHI-5 asks about symptoms in the last 4 weeks. It therefore identifies both transient and chronic symptoms of poor mental health, whereas the self-reported diagnosis variable confirms current or previous symptoms of a chronic nature. This is supported by the sensitivity analysis, where when a cut-point requiring greater symptom severity to be classified as ‘depressed’ (≤46 MHI5 points) was used, those with ‘no depression’ had significantly greater odds of having a core food score in the top quartile (i.e. higher core food

consumption) in 2017. Using a higher cut-point (≤54 MHI5 points), there was no association between depression category and core food score category. This may be because the 'likely depressed' reference group using the higher cut-point is likely to contain a greater number of false positives. Nevertheless, the prospective association between core food score and depressive symptom score remained significant after adjusting for self-reported diagnosis. These findings indicate that while poor diet quality may be a consequence of diagnosable depression, it may also be one of many causative factors in the development of depressive symptoms.

Three important public health implications arise from this paper. Firstly, prioritizing a focus on nutrient dense core foods as opposed to nutrient poor non-core foods may be more important when examining the association between diet quality and mental health. This also suggests that interventions to improve mental health may consider promoting adding a greater variety and volume of core foods rather than primarily focusing on a reduction of non-core foods (Firth et al., 2018). Recent clinical research has shown depression is associated with heightened levels of oxidative stress and inflammation (Berk et al., 2013), though this has recently been called into question (Fried et al., 2019). Depression has also been associated with low serum levels of essential nutrients such as vitamin D, zinc and folate (Anglin et al., 2013; Gilbody et al., 2007; Swardfager et al., 2013). Other potential mechanisms may include dysfunction of the gut microbiome although evidence to date is limited (Valles-Colomer et al., 2019). A higher quality diet which provides adequate amounts of nutrients with antioxidant and anti-inflammatory properties nutrients such as N-acetylcysteine and omega-3 fish oils, other essential nutrients and prebiotic and probiotic food, may therefore play a role in the prevention and treatment of depression. However, conclusive evidence is notoriously difficult to establish (Almeida et al., 2015; Berk et al., 2014; Sanada et al., 2020), one of the reasons being that we do not consume nutrients in isolation and the complex interplay

between nutrients in a complete diet is unlikely to be replicated by nutrient supplementation, and is challenging to identify. The association between diet quality and depression may also be influenced by chronic disease. Poor quality diets increase the risk of many chronic diseases, including cardiovascular disease and type 2 diabetes, which shares common pathways with the development of depression, and the prevalence of depressive symptoms in those diagnosed with these chronic diseases is higher than the general population (Bădescu et al., 2016; Dhar and Barton, 2016; Fung et al., 2007; Hu et al., 2019).

The second and less encouraging finding is that the actual adjusted effect size of diet quality on depressive symptoms was very small. One point higher on the core food score [range 0-17] was associated with a MHI5 score which was 0.102 points higher [range 0-100]. This suggests (i) dietary interventions have limited ability to improve population mental health, and (ii) cost-effective interventions should focus on individuals with poor core food intake. While a systematic review identified evidence of overall significant positive effect of dietary interventions on depressive symptoms in a primarily non-clinical population, findings varied greatly with just over half of the 17 identified studies reporting no effect on mental health outcomes (Opie et al., 2015). However, few randomized controlled trials of dietary interventions in non-clinical populations have change in depression scores as a primary outcome and may not be adequately powered for these outcomes (Opie et al., 2015). There is also preliminary evidence to suggest that dietary intervention is efficacious as an adjunct to traditional therapy for clinical depression (Jacka et al., 2017; Parletta et al., 2019) or in populations with elevated depression symptoms with or without adjunct therapy (Francis et al., 2019). However, selectively induced expectancy of benefit is an acknowledged issue in dietary interventions as blinding is not feasible, and may explain some of the effect (Molendijk et al., 2018b).

The third finding relates to the significant prospective association between self-reported diagnosed depression or anxiety and poorer diet quality. This suggests those with diagnosed depression may benefit from interventions aimed and maintaining or improving core food consumption. This would be done not only with the goal of reducing symptoms of depression, but also reducing risk of metabolic illness. Individuals with depression have a 40% greater risk of developing cardiac disease, hypertension, stroke, diabetes, metabolic syndrome and a BMI ≥30 kg/m^2, contributing to reduced life expectancy and quality of life in this population (Firth et al., 2019). Improving diet quality is one of several key modifiable factors for protecting the physical health of people with depression (Firth et al., 2019) as inadequate consumption of core foods and high sodium intake in particular is a significant risk factor for non-communicable disease mortality and morbidity (Afshin et al., 2019).

These findings highlight that dietary intervention focusing on increasing core food consumption may have a small positive effect on reducing depressive symptoms. However, both diet quality and mental health are poorer in the most disadvantaged members of society who also carry a larger burden of other chronic diseases (Lorant et al., 2003). Improvement in lifestyle behaviors often occur at a much faster pace in the least disadvantaged subpopulations compared with the most disadvantaged, resulting in a widening gap over time (Ding et al., 2015). Health interventions which require mobilization of an individual's resources, whether material or psychological, generally favors those with more resources, thus also tending to increase social inequalities (Capewell and Graham, 2010). Combining traditional public health education and interventions for high-risk individuals with a well-supported 'food justice' movement through community gardens and food baskets, cooking classes and access to cooking equipment might be necessary to improve diet quality across socio-economic groups (Porter, 2018).

Study limitations

While this paper has many strengths, including a large sample, bidirectional analysis including adjustment for baseline values, continuous outcome measures which retains statistical power and does not underestimate the variation in outcome between groups, i.e. assuming someone with an MHI5 score of 5 and 41 points are the same (i.e. 'likely depressed') (Altman and Royston, 2006), as well as a broad range of covariates, it also has limitations. The included population significantly differed to those excluded. This limits generalisability, and findings may not apply to the general Australian population. We used a non-validated measure of core and non-core food consumption, and self-reported diagnosis of depression or anxiety instead of a confirmed diagnosis of depression from medical files, which may have resulted in incomplete adjustment for previous mental illness in the assoiation between core food score and depressive symptoms. Data on alcohol quantity was not available, which limited our ability to adjust for excessive alcohol use. Finally, despite an extensive list of covariates we cannot rule out the effects of confounding by residual and unmeasured variables.

In conclusion, higher core food score, but not non-core food score, was prospectively associated with fewer symptoms of depression. The association was not bidirectional as the depressive symptom score did not have a prospective association with core or non-core food score. However, a self-reported diagnosis of depression was associated with poorer core food score at follow-up and we cannot rule out that poor core food consumption is caused by prior metal illness.

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FIGURE AND TABLE LEGENDS

Figure 1: Participant flow chart

Table 1: Study population characteristics in 2013 by probable diagnosable depression Mental Health Index-5≤54 points

Table 2: Linear regression model testing for associations with Mental Health Index-5 score, core food score and non-core food score in 2017 (n=10,003)

Table 3: Full results linear models testing for associations with Mental Health Index-5 score, core food score and non-core food score in 2017.

Appendix 1: Description of variables included in analysis

Appendix 2: Core food score calculation

Appendix 3: Non-core food score calculation

Appendix 4: Descriptive statistics comparing included and excluded samples.

Appendix 5: Sensitivity analysis using categorical dependent and independent variables

Figure 1: Participant flow chart

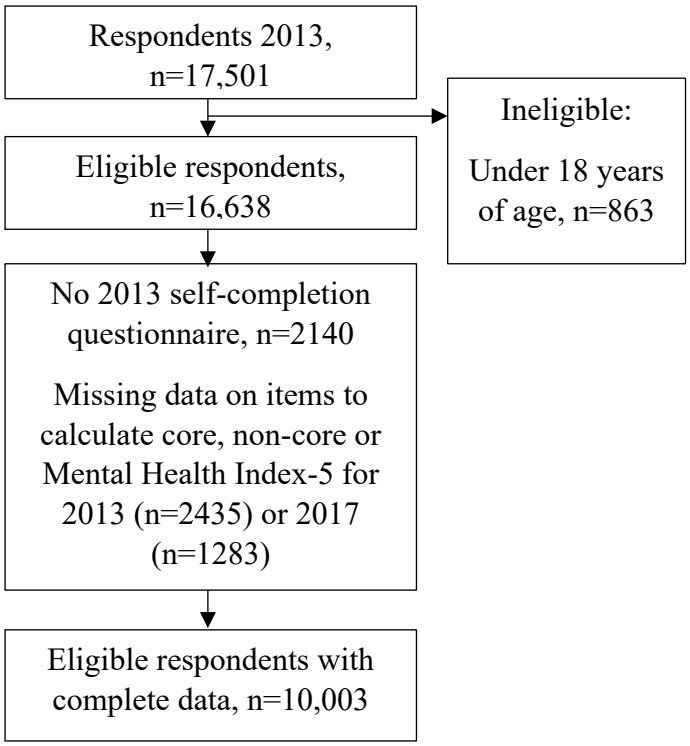

Table 1. Study population characteristics in 2013 by probable diagnosable depression diagnosis

		MHI-5>54[1] n=8020		MHI-5≤54[1] n=1185		Total n=10,003	
	Range	Mean	SD	Mean	SD	Mean	SD
Mental Health Index-5 score**	0 to 100	74.7	11.2	41.3	10.9	75.2	16.7
Core food score**	1 to 19	10.9	2.9	9.9	3.0	10.8	2.9
Average fruit serves eaten per day**	0 to 6	1.4	1.1	1.1	1.0	1.4	1.1
Average vegetable serves eaten per day**	0 to 6	2.4	1.3	2.1	1.3	2.4	1.3
Non-core food score**	0 to 12	3.5	2.0	3.7	2.2	3.6	2.0
Age at baseline, years**	18 to 95	48.8	15.8	47.0	14.7	48.6	15.7
Socio-Economic Index for Areas decile**	1 to 10	5.7	2.8	5.2	2.9	5.7	2.9
Household income per AUD$10,000**	$-15.0 to $130.8	11.9	10.3	9.8	8.8	11.7	10.1
Index of personal support & friendship**	-30 to 30	16.3	9.2	4.3	10.8	14.9	10.2
	Categories	n	%	n	%	n	%
Gender*	Male	4591	52.1	578	48.8	5169	51.7
	Female	4227	47.9	607	51.2	4834	48.3
Education**	High	2600	29.5	262	22.1	2862	28.6
	Medium	4313	48.9	605	51.1	4918	49.2
	Low	1905	21.6	318	26.8	2223	22.2
Partner status**	Partnered	5930	67.3	641	54.1	6571	65.7
	Non-partnered	2888	32.8	544	45.9	3432	34.3
Alcohol use	Low risk	7471	84.7	1029	86.8	8500	85.0
	High risk	1347	15.3	156	13.2	1503	15.0
Smoking**	Never smoker	4869	55.2	558	47.1	5427	54.3
	Former smoker	2624	29.8	330	27.9	2954	29.5
	Smoker	1325	15.0	297	25.1	1622	16.2
Work status**	Daytime work	5501	62.4	579	48.9	6080	60.8
	Night-time work	564	6.4	78	6.6	642	6.4
	Not in workforce	2513	28.5	457	38.6	2970	29.7
	Unemployed	240	2.7	71	6.0	311	3.1
Insomnia symptoms**	No	7400	83.9	618	52.2	8018	80.2
	Yes	1418	16.1	567	47.9	1985	19.8
Sleep duration** [2]	Recommended	4201	47.6	450	38.0	4651	46.5
	Shorter	3909	44.3	633	53.4	4542	46.5
	Longer	708	8.0	102	8.6	810	8.1
Physical activity level**	High	3260	37.0	311	26.2	3571	35.7
	Moderate	3050	34.6	408	34.4	3458	34.6
	Low	2508	28.4	466	39.3	2974	29.7
BMI category**	<18.5 kg/m^2	175	2.0	36	3.0	211	2.1
	18.5-24.9 kg/m^2	3327	37.7	428	36.1	3755	37.5
	25.0-29.9 kg/m^2	3185	36.1	371	31.3	3556	35.6
	≥30.0 kg/m^2	2131	24.2	350	29.5	2481	24.8
Weight satisfaction**	Satisfied	3133	35.5	282	23.8	3415	34.1
	Neutral	2068	23.5	267	22.5	2335	23.3
	Dissatisfied	3617	41.0	636	56.7	4253	42.5
Stressful life event in last year** [3]	No	5147	58.4	558	47.1	5705	57.0
	Yes	3671	41.6	627	52.9	4298	43.0
Chronic disease diagnosis** [4]	No	5124	58.1	427	36.0	5551	55.5
	Yes	3694	41.9	758	64.0	4452	44.5
Previous/current diagnosis of depression**	No	8101	91.9	676	57.1	8777	87.7
	Yes	717	8.1	509	43.0	1226	12.3

[1]MHI-5 cut-off for probable diagnosable depression≤54 points; [2]Shorter sleep:<7 hours; Longer sleep: >9 hrs if <65yo, >8hrs if ≥65yo; 3Stressful life events: separated/reunited with partner, victim of property crime/violence, jailed/close family member jailed, injury to family member, worsening finances, fired/ change in jobs, retired or moving house in the 12 months preceding the 2013 survey. [4]Chronic diseases: arthritis/osteoporosis, asthma, cancer, chronic bronchitis/emphysema, Type 1/Type 2 diabetes, heart disease, hypertension, any other serious circulatory condition; T-test continuous variables/Chi-square test categorical variables: *P<0.05; **P<0.001

Table 2. Linear regression model testing for associations with Mental Health Index-5 score, core food score and non-core food score in 2017 (n=10,003)

Outcome	Independent variables	Model a		Model b	
		β	95%CI	β	95%CI
Mental Health Index-5, 2017	Core food score, 2013	0.302	(0.210, 0.393)	0.124	(0.029, 0.219)
	Non-core food score, 2013	-0.009	(-0.143, 0.125)	-0.018	(-0.115, 0.152)
	MHI5 score, 2013	0.599	(0.579, 0.620)	0.554	(0.532, 0.576)
Core food score, 2017	Core food score, 2013	0.446	(0.434, 0.459)	0.471	(0.457,0.485)
	Non-core food score, 2013	0.023	(0.005, 0.042)	0.013	(-0.006, 0.032)
	MHI5 score, 2013	0.005	(0.002, 0.007)	0.001	(-0.001, 0.004)
Non-core food score, 2017	Core food score, 2013	-0.022	(-0.033, -0.010)	-0.018	(-0.029, -0.006)
	Non- core food score, 2013	0.522	(0.505, 0.539)	0.514	(0.497, 0.531)
	MHI5 score 2013	-0.001	(-0.003, 0.001)	-0.002	(-0.004, 0.001)

Mental Health Index -Model b: Adjusted for age, sex, household income, work status, chronic disease and BMI category, smoking status, insomnia symptoms, sleep duration, physical activity; Core food score-Model b: Adjusted for age, sex, marital status, SEIFA decile, education level, work status, chronic disease and BMI category, smoking status, alcohol use, insomnia symptoms, sleep duration, physical activity, loneliness and weight satisfaction; Non-core food score-Model b: Adjusted for age, sex, marital status, SEIFA decile, education level, BMI category, insomnia symptoms, sleep duration, physical activity, loneliness and weight satisfaction.

Table 3. Full results linear models testing for associations with Mental Health Index-5 score, core food score and non-core food score in 2017.

Baseline variables, 2013		Full Model c Mental Health Index-5 2017		Full Model c Core food score 2017		Full Model c Non-core food score 2017	
		β	95%CI	β	95%CI	β	95%CI
Core food score[1]	Score 0-19	0.102	(0.008, 0.196)	0.470	(0.457, 0.485)	-0.017	(-0.035, -0.005)
Non-core food score[1]	Score 0-12	0.030	(-0.102, 0.162)	0.013	(-0.006, 0.033)	0.514	(0.497, 0.531)
MHI5 score 2013[2]	Score 0-100	0.466	(0.441, 0.492)	-0.001	(-0.004, 0.002)	-0.002	(-0.005, 0.001)
Age	Years	0.115	(0.094, 0.136)	0.004	(0.001, 0.007)	-0.002	(-0.001, 0.004)
Sex (ref: male)	Female	0.106	(-0.427, 0.641)	0.016	(-0.063, 0.095)	-0.060	(-0.130, 0.010)
Social Economic Index of Financial Advantage	Decile (1-10)			0.039	(0.025, 0.054)	-0.035	(-0.048, 0.022)
Household income	Per AU$10,000	0.038	(0.010, 0.066)				
Marital status (ref: partnered)	Non-partnered			-0.159	(-0.244, -0.074)	-0.175	(-0.250, -0.099)
Education level (ref: high)	Medium			-0.360	(-0.457, -0.264)	0.004	(-0.088, 0.097)
	Low			-0.685	(-0.808, -0.562)	-0.091	(-0.198, 0.016)
Work status (ref: daytime work)	Night-time work	0.646	(-0.456, 1.749)	-0.101	(-0.263, 0.062)		
	Not in workforce	-1.417	(-2.102, -0.732)	0.028	(-0.072, 0.128)		
	Unemployed	0.039	(-1.529, 1.608)	-0.055	(-0.285, 0.175)		
Alcohol consumption (ref: <5 days/week)	≥5 days per week			0.102	(0.012, 0.216)		
Smoking (ref: never smoked)	Former smoker	0.121	(-0.501, 0.743)	-0.138	(-0.230, 0.045)		
	Current smoker	-1.217	(-2.010, -0.424)	-0.256	(-0.474, -0.238)		
Body mass index category	<18.5 kg/m^2	0.415	(-1.468, 2.297)	-0.214	(-0.491, 0.063)	-0.183	(-0.428, 0.062)
(ref: 18.5-24.9 kg/m^2)	25-29.9 kg/m^2	0.567	(-0.095, 1.228)	-0.102	(-0.200, -0.005)	0.075	(0.011, 0.161)
	≥30.0 kg/m^2	0.399	(-0.399, 1.196)	-0.121	(-0.239, -0.003)	0.013	(-0.117, 0.091)
Insomnia symptoms (ref: no)	Yes	-1.990	(-2.708, -1.258)	-0.104	(-0.212, 0.003)	-0.043	(-0.139, 0.052)
Sleep duration (ref: recommended) [4]	Shorter	0.235	(-0.344, 0.813)	-0.066	(-0.151, 0.019)	-0.060	(-0.135, 0.015)
	Longer	-0.665	(-1.701, 0.372)	-0.146	(-0.299, 0.006)	0.144	(0.010, 0.278)
Physical activity (ref: high)	Moderate	-0.243	(-0.886, 0.400)	0.078	(-0.016, 0.173)	-0.024	(-0.108, 0.059)
	Low	-0.470	(-1.152, 0.213)	-0.061	(-0.162, 0.039)	-0.044	(-0.132, 0.045)
Weight satisfaction (ref: satisfied)	Neutral	-0.193	(-0.927, 0.540)	0.078	(-0.030, 0.186)	-0.073	(-0.168, 0.022)
	Dissatisfied	-1.236	(-1.943, 0.528)	0.049	(-0.055, 0.152)	-0.066	(-0.158, 0.026)
Stressful life events, last 12 months (ref: no)[5]	Yes	-0.397	(-0.947, 0.153)				
Index of personal support & friendship (loneliness) [6]	Score (-30 to 30)	0.191	(0.160, 0.223)	0.003	(-0.001, 0.008)	-0.001	(-0.005, 0.002)
Chronic disease diagnosis (ref: none)[3]	Yes, one or more	-0.630	(-1.295, 0.035)				
Previous/ current depression diagnosis (ref: no)	Yes	-4.278	(-5.251, -3.305)	-0.198	(-0.329, -0.067)	-0.036	(-0.151, 0.080)

[1]Higher score=more frequent consumption; [2]Higher score=better mental health; [3]Chronic diseases: arthritis/osteoporosis, asthma, cancer, chronic bronchitis or emphysema, Type 1 diabetes, Type 2 diabetes, heart disease, high blood pressure or hypertension, any other serious circulatory condition; [4]Shorter sleep:<7 hours/ longer sleep:>9 hrs if <65yo, >8hrs if ≥65yo; [5]Stressful life events: separated or reunited with partner, victim of property crime/violence, jailed/close family member jailed, injury to family member, worsening finances, fired/changed jobs, retired or moved house in the 12 months preceding the 2013 survey; [6]Higher score=more social support

0

1

2