

# BMJ Open

## Fruit and vegetable consumption and the prevalence and incidence of psychological distress in a large cohort of middle-aged and older Australians

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2016-014201
Article Type:	Research
Date Submitted by the Author:	08-Sep-2016
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<b>Primary Subject Heading</b>:	Mental health
Secondary Subject Heading:	Nutrition and metabolism
Keywords:	MENTAL HEALTH, NUTRITION & DIETETICS, Depression & mood disorders < PSYCHIATRY

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**Title**

Fruit and vegetable consumption and the prevalence and incidence of psychological distress in a large cohort of middle-aged and older Australians

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**Main text word count** 3,000 words

**Key words**

Fruit, vegetable, mental health, depression

For peer review only

**ABSTRACT**

**Objectives.** Growing evidence suggests a link between diet and mental health. This study aimed to investigate the association between fruit and vegetable consumption and the prevalence and incidence of psychological distress in middle-aged and older Australians.

**Design.** Cross-sectional and prospective.

**Setting.** New South Wales, Australia.

**Methods.** A sample of 60,404 adults aged  $\geq 45$  years completed baseline (2006-2008) and follow-up (2010) questionnaires. Psychological distress was assessed using the validated Kessler psychological distress (K10) scale, a 10-item questionnaire measuring general anxiety and depression. Psychological distress was defined as the presence of high-to-very high levels of distress (K10 score  $\geq 22$ ). Usual fruit and vegetable consumption was assessed using short validated questions. The association between fruit and vegetable consumption and the prevalence or incidence of psychological distress was examined using logistic regression models.

**Results.** At baseline, 5.6% reported psychological distress. During a mean 2.7 years of follow-up, 4.0% of those who did not report distress at baseline reported distress at follow-up. Fruit and vegetable consumption, considered separately or combined, was associated with a lower prevalence of psychological distress even after adjustment for socio-demographic characteristics and lifestyle risk factors. Fruit and vegetable consumption, measured separately or combined, was associated with a lower incidence of psychological distress in minimally-adjusted models. Most of these associations remained significant at medium levels of intake but were no longer significant at the highest intake levels in fully-adjusted models.

**Conclusions.** Increasing fruit and vegetable consumption may help reduce psychological distress in middle-aged and older adults. However, the association of fruit and vegetable consumption with the incidence of psychological distress requires further investigation.

## STRENGTHS AND LIMITATIONS OF THIS STUDY

- This study included a large sample size of 60,404 participants for cross-sectional analyses and 54,345 participants for longitudinal analyses.
- Analyses were adjusted for multiple socio-demographic and lifestyle-related covariates.
- The well-validated Kessler psychological distress (K10) scale was used to assess psychological distress.
- The relatively short follow-up time may have been insufficient to observe the full extent of long-term associations between fruit and vegetable intake and psychological distress.

INTRODUCTION

There has been a global call for action by the World Health Organisation (WHO) to make mental health a global development priority.<sup>1</sup> Mental disorders affect a tenth of the world population and represent 30% of non-fatal global burden of disease.<sup>2</sup> Depression alone is a leading cause of disability worldwide<sup>3</sup> and is projected to rank among the three leading causes of global disease burden by 2030.<sup>4</sup> There is an urgent call for public health strategies aimed at preventing the onset on common mental disorders, such as depression.

There has been considerable interest in the relationship between psychological wellbeing and lifestyle factors, with growing evidence for a link between mental health and diet.<sup>5-7</sup> The role of fruit and vegetables has received increasing attention, given evidence for its protective effects against chronic diseases such as cardiovascular disease and cancer.<sup>8,9</sup> Diets low in fruit have been recently identified as the leading dietary risk factor for global burden of disease.<sup>10</sup>

Findings from a recent meta-analysis, based on seven cross-sectional and four prospective studies, suggest that both fruit and vegetable consumption are significantly associated with a lower risk of depression.<sup>11</sup> Several large cross-sectional studies have shown that greater consumption of fruit and vegetables is associated with better mental health, including lower odds of depression and psychological distress, in the general population.<sup>12,13</sup> Fewer studies have investigated the longitudinal association between fruit and vegetable intake and depression. Higher consumption of fruit and/or vegetables was associated with lower odds of incident depression in middle-aged Australian women followed over six years,<sup>14</sup> post-menopausal Australian women followed for three years<sup>15</sup> and Spanish adults followed over four years.<sup>16</sup> These findings are in agreement with previous cross-sectional and longitudinal studies that have found healthy dietary patterns, including high intakes of fruit and vegetables, to be associated with a lower risk of depression and anxiety, particularly in middle-aged and older adults.<sup>17-20</sup>

Depression in later life is associated with increased morbidity and mortality, and decreased physical, cognitive and social functioning.<sup>21</sup> Improving mental health is an important public health challenge to address in an ageing population with a higher life expectancy.<sup>1</sup> Therefore, the main objective of this study was to investigate the association between fruit and vegetable consumption and the prevalence and incidence of psychological distress in a large cohort of middle-aged and older Australians.

## METHODS

### Study population

The baseline data were from the Sax Institute's 45 and Up Study, a large-scale (n=267,153) population study of men and women aged 45 years and over, who were randomly sampled from the general population of New South Wales (NSW), Australia. From January 2006 to December 2008, eligible individuals joined the study by completing a postal questionnaire and providing written consent for participation and long-term follow-up. The 45 and Up Study has been described in detail elsewhere.<sup>22</sup> A subsample of the 45 and Up Study was followed-up in 2010 (i.e, the Social, Economic, and Environmental Factor [SEEF] Study), with the first 100,000 participants of the 45 and Up Study invited to complete the SEEF questionnaire (60.4% response rate). For cross-sectional analyses, the analytic sample included 60,404 participants (53.6% women). For longitudinal analyses, participants who reported on the baseline questionnaire that they had been treated for depression/anxiety in the last month (n=3,796), and/or taking anti-depressant medication for most of the last four weeks (n=700), and/or with high/very high levels of psychological distress (n=3,030; defined as having a Kessler psychological distress scale [K10] score  $\geq 22$ <sup>23</sup> were excluded (n=6,067), leaving a final sample of 54,345 participants. A participant flow chart for this study is provided in **Figure 1**. The 45 and Up Study was granted ethical approval by the University of NSW Human Research Ethics Committee (reference HREC 05035/HREC 10186) and the SEEF Study by the University of Sydney Human Research Ethics Committee (reference 10-2009/12187).

### Measurement

The 45 and Up Study and SEEF Study questionnaires include questions on socio-demographic characteristics, personal and medical history, and lifestyle risk factors (available from <http://www.saxinstitute.org.au/our-work/45-up-study/questionnaires/>).

### Outcome

At both baseline and follow-up, participants' general level of psychological distress was assessed using the well-validated and widely used K10 scale, a 10-item questionnaire about anxiety and depression symptoms experienced in the last four weeks.<sup>23</sup> A five-point response scale (none of the time, a little of the time, some of the time, most of the time, all of the time) is used for each item, with scores ranging from 1 (none of the time) to 5 (all of the time). Scores to each question are added up to form the total K10 score, with a possible range of 10-50. For this study, score groupings and categories of psychological distress routinely used by the Australian

Bureau of Statistics for national health surveys were adopted with total scores of: 10-15, 16-21, 22-29 and 30-50 indicating low, moderate, high and very high levels of psychological distress, respectively.

High K10 scores are strongly correlated with current WHO's Composite International Diagnostic Interview (CIDI) diagnosis of anxiety and affective disorders.<sup>23</sup> Prevalence of psychological distress at baseline was defined as the presence of high-to-very high levels of psychological distress (K10 score $\geq$ 22). Incidence of psychological distress was defined as: 1) not being treated for anxiety/depression in the last month, and/or not taking anti-depressant medication for most of the last four weeks, and/or not having high/very high levels of psychological distress (K10 score $<$ 22) at baseline, and 2) the presence of high-to-very high levels of psychological distress (K10 score $\geq$ 22) at follow-up. Psychological distress was treated as binary outcome variable in the analyses (K10 score $<$ 22 vs.  $\geq$ 22; i.e. low-to-moderate vs high-to-very high levels of distress).

Exposure

Usual fruit and vegetable consumption was assessed using the following validated short questions commonly used in health monitoring and surveillance:<sup>24</sup>

1. "About how many serves of fruit do you usually have each day?" One serve of fruit was defined as one medium piece or two small pieces of fresh fruit, or one cup of diced or canned fruit pieces.
2. "About how many serves of vegetables do you usually eat each day?" One serve of vegetables was defined as half a cup of cooked vegetables (including potatoes) or one cup of raw vegetables (e.g. salad).

Total fruit and vegetable consumption was derived by summing the reported number of fruit and vegetables consumed daily. Fruit and vegetable consumption, considered separately and combined, was categorised into tertiles.

Covariates

Covariates included baseline self-reported socio-demographic characteristics such as sex, age, highest level of education ( $\leq$ 10 years of schooling, high school/trade apprenticeship/certificate/diploma, university degree/higher), marital status (married/living with a partner vs. single/widowed/divorced/separated), household annual income ( $<$ \$30,000, \$30,000-\$69,999,  $\geq$ \$70,000, would rather not answer this question), self-reported history of



major chronic disease (cancer other than non-melanoma skin cancer, cardiovascular disease [heart disease, stroke or blood clot], diabetes or hypertension; yes vs. no) and the following lifestyle risk factors: body mass index (BMI; derived from self-reported height and weight), alcohol intake ( $\leq 14$  or  $> 14$  drinks/week), smoking status (current smoker vs. not currently a smoker) and physical activity levels (assessed using validated questions from the Active Australia Survey;<sup>25</sup> categorised as  $< 150$ , 150-299 and  $\geq 300$  minutes/week).

### Statistical analysis

The association between fruit and vegetable consumption and the prevalence/ incidence of psychological distress (K10 score  $\geq 22$ ) was examined using logistic regression models. Odds ratios (ORs) with 95% confidence intervals (CI) are presented for unadjusted, age- and sex-adjusted, and models adjusted for all covariates as described above. We tested effect modification by sex by fitting interaction terms. Interactions with p-values  $< 0.1$  were considered statistically significant. To examine potential sex differences, the analyses were further stratified by sex. If one out of ten responses to K10 scale questions was missing (for 3.2% and 2.8% of participants included in cross-sectional and longitudinal analyses respectively), the missing value was imputed using the mean score across the other nine questions.<sup>26</sup> If more than one response was missing, K10 scores were considered as missing. P-values  $< 0.05$  were considered statistically significant. All analyses were conducted using SPSS version 22 (IBM Corp., Armonk, NY).

RESULTS

Participant characteristics

**Table 1** shows baseline participant characteristics based on K10 score at follow-up. Overall, the mean age (standard deviation [SD]) of participants was 62.2 (10.6) years, more than half (53.6%) were women, over a quarter (26%) had a university degree/higher, over three-quarters (78%) were in a married/de facto relationship, and a quarter (25.7%) reported a household annual income  $\geq$ \$70,000. The mean (SD) serves of fruit and vegetables were respectively 2.0 (1.4) and 3.9 (2.6) serves/day. The average follow-up time period was 2.7 (0.9) years. Participants with high-to-very high levels of psychological distress (6.6%) at follow-up were more likely to be women, relatively younger, less educated and have a lower household annual income. These participants were also more likely to: have a higher BMI, be a current smoker, be less physically active and have a history of chronic disease.

Prevalence of psychological distress

At baseline, 5.6% reported high-to-very high levels of psychological distress. The ORs for the association between separate or combined fruit and vegetable consumption and the prevalence of high-to-very high levels of psychological distress ( $K10 \geq 22$ ) are presented in **Table 2**. Consumption of fruit and vegetables, considered separately or combined, was consistently associated with a lower prevalence of psychological distress. Following adjustment for all covariates, these associations were slightly attenuated compared with the unadjusted model but remained significant. Other covariates which were significantly associated with the prevalence of psychological distress were being relatively younger, single/divorced/widowed/separated, a current smoker, lower education, lower household annual income, lower BMI, low physical activity levels and a self-reported history of chronic disease. There was a significant interaction between combined fruit and vegetable consumption and sex ( $p=0.049$ ). When analyses were stratified by sex (**Table 3**), the association between fruit and vegetable consumption, measured separately or combined, and the prevalence of psychological distress was markedly stronger in women and was significant for all consumption tertiles ( $p \leq 0.001$ ). Among men, only those in the medium tertiles of separate fruit and vegetable consumption had significantly lower odds of psychological distress.

Incidence of psychological distress

During an average of 2.7 years of follow-up, 4.0% of those who did not report distress at baseline reported distress at follow-up. **Table 4** shows the association between fruit and

**Table 1.** Baseline characteristics of participants according to K10 score at follow-up (n=60,404; 2006-2010)<sup>a</sup>

Variable	All	K10 score at follow-up <sup>b</sup>		
		<22	≥22	p-value <sup>c</sup>
Sample size	60,404	54,950	3,904	
Mean (SD) follow-up time (years)	2.67 (0.93)	2.67 (0.93)	2.71 (0.95)	0.003
Women (%)	53.6	53.3	56.2	<0.001
Mean (SD) age (years)	62.2 (10.6)	62.1 (10.4)	60.7 (10.8)	<0.001
Highest education (%)				<0.001
University and higher	26.2	27.3	17.6	
High school/trade apprenticeship/certificate/ Diploma	42.7	43.0	41.5	
≤10 years	31.1	29.7	40.9	
Married/living with a partner (%)	78.0	78.9	69.6	<0.001
Household annual income (%)				<0.001
<\$30,000	29.5	27.7	45.0	
\$30,000-\$69,999	28.9	29.4	25.1	
≥\$70,000	25.7	27.1	14.5	
Did not specify	15.9	15.8	15.4	
BMI category (%)				<0.001

Underweight (<18.5 kg/m <sup>2</sup> )	1.2	1.2	2.0	
Normal weight (18.5 to <25 kg/m <sup>2</sup> )	37.9	38.5	29.7	
Overweight or obese (≥25 kg/m <sup>2</sup> )	60.9	60.4	68.3	
Current smoker (%)	5.7	5.2	13.6	<0.001
Usually consumes >14 alcohol drinks/week	14.9	15.1	13.9	0.05
Mean (SD) fruit consumption (serves/day)	2.0 (1.4)	2.1 (1.4)	1.9 (1.5)	<0.001
Mean (SD) vegetable consumption (serves/day)	3.9 (2.6)	4.0 (2.6)	3.8 (2.7)	<0.001
Physical activity level (%)				<0.001
<150 minutes/week	18.9	17.5	28.0	
150 to 299 minutes/week	16.6	16.6	18.7	
≥300 minutes/week	64.4	65.9	53.4	
History of chronic disease (%)	51.8	50.9	57.9	<0.001

Abbreviations: BMI=body mass index, K10=Kessler Psychological Distress Scale, SD=standard deviation.

<sup>a</sup> Data are presented as means (SD) or percentages (%).

<sup>b</sup> The total K10 score is based on a 10-item questionnaire about anxiety and depression symptoms experienced in the last four weeks.<sup>23</sup> Participants were grouped according to K10 scores and categorised as at “low-to-moderate risk” (K10<22) or at “high-to-very high risk” of psychological distress (≥22). K10 data was missing for n=1,558.

<sup>c</sup> P-value from independent t-tests for continuous variables and from chi-square tests for categorical variables.

**Table 2.** Unadjusted and adjusted odds ratios for the baseline association between fruit and vegetable consumption and high-to-very high levels of psychological distress (K10<sup>a</sup>≥22 vs. K10<sup>a</sup><22).

	Unadjusted OR (95% CI)	P-value	Age and sex-adjusted OR (95% CI)	P-value	Fully-adjusted OR <sup>b</sup> (95% CI)	P-value
<i>Tertiles</i>						
Fruit						
0-1 serve/day	1.0 (reference)		1.0 (reference)		1.0 (reference)	
>1-2 serves/day	0.66 (0.60, 0.72)	<0.001	0.65 (0.59, 0.71)	<0.001	0.72 (0.65, 0.80)	<0.001
>2 serves/day	0.71 (0.65, 0.78)	<0.001	0.72 (0.65, 0.79)	<0.001	0.87 (0.79, 0.97)	0.01
Vegetables						
0-2 serves/day	1.0 (reference)		1.0 (reference)		1.0 (reference)	
>2-4 serves/day	0.73 (0.66, 0.80)	<0.001	0.70 (0.64, 0.77)	<0.001	0.81 (0.73, 0.90)	<0.001
>4 serves/day	0.76 (0.70, 0.84)	<0.001	0.75 (0.68, 0.82)	<0.001	0.85 (0.76, 0.94)	<0.001
Fruit and vegetables						
0-4 serves/day	1.0 (reference)		1.0 (reference)		1.0 (reference)	
>4-7 serves/day	0.73 (0.67, 0.79)	<0.001	0.70 (0.64, 0.77)	<0.001	0.82 (0.74, 0.90)	<0.001
>7 serves/day	0.71 (0.64, 0.78)	<0.001	0.70 (0.63, 0.77)	<0.001	0.82 (0.74, 0.92)	0.001

Abbreviations: CI=confidence interval, K10=Kessler Psychological Distress Scale, OR=odds ratio.

<sup>a</sup> The total K10 score is based on a 10-item questionnaire about anxiety and depression symptoms experienced in the last four weeks.<sup>23</sup> Possible K10 scores range from 10-50 with scores≥22 indicating high-to-very-high levels of psychological distress.

<sup>b</sup> Adjusted for baseline age, sex, highest education level, marital status, household annual income, body mass index category, smoking status, alcohol intake, physical activity levels and a history of chronic disease.

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**Table 3.** Adjusted odds ratios for the prevalence and incidence of high-to-very high levels of psychological distress (K10<sup>a</sup>≥22 vs. K10<sup>a</sup><22) by baseline fruit and vegetable consumption and stratified by sex.

	Cross-sectional analysis				Longitudinal analysis <sup>c</sup>			
	Male		Female		Male		Female	
	Fully-adjusted OR <sup>b</sup> (95% CI)	P-value	Fully-adjusted OR <sup>b</sup> (95% CI)	P-value	Fully-adjusted OR <sup>b</sup> (95% CI)	P-value	Fully-adjusted OR <sup>b</sup> (95% CI)	P-value
<i>Tertiles</i>								
<i>Fruit</i>								
0-1 serve/day	1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)	
>1-2 serves/day	0.78 (0.67, 0.91)	0.002	0.67 (0.59, 0.77)	<0.001	0.95 (0.80, 1.13)	0.56	0.84 (0.71, 0.995)	0.04
>2 serves/day	0.99 (0.84, 1.17)	0.95	0.79 (0.69, 0.91)	0.001	0.98 (0.81, 1.19)	0.85	0.84 (0.70, 1.0)	0.06
<i>Vegetables</i>								
0-2 serves/day	1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)	
>2-4 serves/day	0.80 (0.69, 0.93)	0.004	0.80 (0.70, 0.92)	0.001	0.94 (0.79, 1.11)	0.45	0.82 (0.69, 0.98)	0.03
>4 serves/day	0.91 (0.78, 1.06)	0.23	0.80 (0.70, 0.92)	0.001	0.94 (0.78, 1.13)	0.51	0.89 (0.75, 1.05)	0.17
<i>Fruit and vegetables</i>								
0-4 serves/day	1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)	
>4-7 serves/day	0.92 (0.80, 1.07)	0.28	0.73 (0.64, 0.83)	<0.001	0.98 (0.83, 1.16)	0.82	0.77 (0.65, 0.91)	0.002
>7 serves/day	0.91 (0.76, 1.09)	0.30	0.75 (0.65, 0.87)	<0.001	0.94 (0.77, 1.15)	0.52	0.86 (0.72, 1.02)	0.09

Abbreviations: CI=confidence interval, K10=Kessler Psychological Distress Scale, OR=odds ratio.

<sup>a</sup> The total K10 score is based on a 10-item questionnaire about anxiety and depression symptoms experienced in the last four weeks.<sup>23</sup> Possible K10 scores range from 10-50 with scores≥22 indicating high-to-very-high levels of psychological distress.

<sup>b</sup> Adjusted for baseline age, sex, highest education level, marital status, household annual income, body mass index category, smoking status, alcoholic intake, physical activity levels and a history of chronic disease.

<sup>c</sup> Participants who reported having been recently treated for depression/anxiety and/or taking antidepressant medication and/or with a K10 score ≥22 (n=6,067) at baseline were excluded from longitudinal analyses.

**Table 4.** Unadjusted and adjusted odds ratios for the incidence of high-to-very high levels of psychological distress (K10<sup>a</sup>≥22) by baseline fruit and vegetable consumption.

	Unadjusted OR (95% CI)	P-value	Age and sex-adjusted OR (95% CI)	P-value	Fully-adjusted OR <sup>b</sup> (95% CI)	P-value
<i>Tertiles</i>						
Fruit						
0-1 serve/day	1.0 (reference)		1.0 (reference)		1.0 (reference)	
>1-2 serves/day	0.80 (0.72, 0.89)	<0.001	0.79 (0.71, 0.88)	<0.001	0.89 (0.79, 1.01)	0.07
>2 serves/day	0.79 (0.70, 0.88)	<0.001	0.78 (0.69, 0.87)	<0.001	0.90 (0.79, 1.03)	0.11
Vegetables						
0-2 serves/day	1.0 (reference)		1.0 (reference)		1.0 (reference)	
>2-4 serves/day	0.77 (0.69, 0.86)	<0.001	0.76 (0.68, 0.85)	<0.001	0.88 (0.78, 0.99)	0.03
>4 serves/day	0.87 (0.78, 0.97)	0.01	0.85 (0.76, 0.95)	0.003	0.92 (0.81, 1.04)	0.16
Fruit and vegetables						
0-4 serves/day	1.0 (reference)		1.0 (reference)		1.0 (reference)	
>4-7 serves/day	0.77 (0.69, 0.85)	<0.001	0.75 (0.67, 0.83)	<0.001	0.86 (0.77, 0.97)	0.01
>7 serves/day	0.85 (0.76, 0.95)	0.005	0.82 (0.73, 0.93)	0.001	0.90 (0.79, 1.03)	0.12

Abbreviations: CI=confidence interval, K10=Kessler Psychological Distress Scale, OR=odds ratio.

Participants who reported having been recently treated for depression/anxiety and/or taking antidepressant medication and/or with a K10<sup>a</sup> score ≥22 (n=6,067) at baseline were excluded from this analysis.

<sup>a</sup> The total K10 score is based on a 10-item questionnaire about anxiety and depression symptoms experienced in the last four weeks.<sup>23</sup> Possible K10 scores range from 10-50 with scores ≥22 indicating high-to-very-high levels of psychological distress.

<sup>b</sup> Adjusted for baseline age, sex, highest education level, marital status, household annual income, body mass index category, smoking status, alcohol intake, physical activity levels and a history of chronic disease.

vegetable consumption and the incidence of high-to-very high levels of psychological distress ( $K10 \geq 22$ ). Similar to cross-sectional findings, fruit and vegetable consumption, measured separately or combined, was significantly associated with a lower incidence of psychological distress in both unadjusted and minimally-adjusted models. In the fully-adjusted models, the medium tertiles of both combined fruit and vegetable consumption, and separate vegetable consumption, remained significantly associated with reduced odds of psychological distress. The association between the medium tertile of fruit consumption and the incidence of psychological distress approached significance ( $p=0.07$ ). However, the association between the highest tertile of consumption and the incidence of psychological distress did not remain significant for consumption of fruit and vegetables considered either separately or combined. Other covariates which were significantly associated with the incidence of psychological distress were being relatively younger, single/divorced/widowed/separated, a current smoker, lower education, lower household annual income, lower alcohol intake, lower BMI, low physical activity levels and a self-reported history of chronic disease. There was a significant interaction between combined fruit and vegetable consumption and sex ( $p=0.08$ ). When analyses were stratified by sex (**Table 3**), the association between fruit and vegetable consumption, considered separately or combined, and the incidence of psychological distress was stronger in women and significant for all consumption tertiles except for the highest fruit ( $p=0.06$ ) and vegetable tertiles ( $p=0.17$ ). There was no significant association between consumption of fruit and vegetables and the incidence of psychological distress in men.

**Discussion**

In this large cohort of middle-aged and older Australian adults, consumption of fruit and vegetables was significantly associated with the prevalence of psychological distress even after accounting for socio-demographic characteristics and other lifestyle risk factors. The association between fruit and vegetable intake and the incidence of psychological distress was significant after accounting for age and sex. After adjustment for all possible confounders, this association remained mostly significant at medium levels of intake, but did not remain significant at the highest levels of intake. When considered separately in each sex, the association of fruit and vegetable consumption with either the prevalence or incidence of psychological distress was stronger in women, with no clear associations with the incidence of psychological distress in men.



Findings in this study are in agreement with those from a recent meta-analysis, based on seven cross-sectional and four cohort studies, which has found separate fruit and vegetable consumption to be inversely associated with the risk of depression.<sup>11</sup> Although findings from individual cross-sectional and prospective studies were mixed, in subgroup analysis by study design, the meta-analysis showed significant associations in both cross-sectional and prospective studies for fruit intake, and in prospective studies only for vegetable intake. In relation to combined fruit and vegetable consumption, several large cross-sectional studies have also demonstrated significant inverse associations with psychological wellbeing, even after accounting for multiple covariates.<sup>12,13</sup> Among 80,000 randomly selected British adults, a positive association between combined fruit and vegetable consumption and wellbeing, assessed using seven different measures of mental health, was shown in three separate data sets.<sup>13</sup> In a repeated cross-sectional study of 296,121 Canadians with five waves of a national, population-based survey, lower odds of depression and psychological distress were consistently associated with greater combined fruit and vegetable consumption.<sup>13</sup>

Our longitudinal findings add to the limited evidence base for an association between fruit and vegetable consumption and the incidence of psychological distress. Although longitudinal associations with psychological distress did not remain significant at higher levels of fruit and vegetable intake, the direction of these associations was in agreement with findings from previous studies. Among the few prospective studies which have examined the relationship between fruit and vegetable intake and the incidence of depression, mostly in similar-aged samples,<sup>14-16, 27</sup> all but one study<sup>27</sup> have shown significant protective effects of fruit<sup>14,16</sup> or both fruit and vegetables.<sup>15</sup> A recent study conducted among a nationally representative sample of 12,385 Australian adults, reported that combined fruit and vegetable consumption was predictive of increased happiness, life satisfaction and wellbeing, with improvements observed within two years.<sup>28</sup> Overall, differences in findings between studies could be due to several factors which can vary including assessment methods of fruit and vegetable consumption and/or psychological wellbeing, participant characteristics, adjustment for covariates and follow-up periods.

This study is among the first to report associations between fruit and vegetable consumption and psychological wellbeing separately for men and women. Sex was a significant effect modifier of the association between fruit and vegetable consumption and psychological distress. We found that fruit and vegetables were more protective for women than men, suggesting that women may be more responsive to the effects of fruit and vegetables. It is possible that there

may be a true physiological difference between men and women, although a mechanism that could explain this difference remains unclear, or perhaps women more accurately report consumption of fruit and vegetables than men. However, these preliminary findings need to be confirmed by additional studies.

Although these remain to be elucidated, several mechanisms may underlie the relationship between high fruit and vegetable consumption and greater psychological wellbeing.<sup>29</sup> Fruit and vegetables are rich in micronutrients and phytochemicals that may help reduce oxidative stress and inflammation, processes that can have detrimental effects on mental health. For example, antioxidants such as vitamins C, E and polyphenols may help reduce oxidative stress while the mineral magnesium has been associated with lower levels of C-reactive protein, a marker of low-grade inflammation.<sup>29</sup> Deficiencies in B-vitamins such as folic acid (vitamin B9) and vitamin B12 have been associated with depression.<sup>30</sup> Low levels of these vitamins can cause high homocysteine levels which in turn can impair methylation processes involved in the synthesis and metabolism of neurotransmitters that may affect mood.<sup>31</sup> Other minerals such as calcium and iron involved in brain function processes could also play a role in the development of depression. In addition, B-vitamins such as vitamin B12 may exert an influence on neurotransmitters and thereby affect changes in mood.

**Strengths and limitations**

This study had several strengths including a large sample size, a prospective design and the inclusion of multiple socio-demographic and lifestyle-related covariates and the use of the well-validated K10 scale to assess psychological distress. High K10 scores are strongly correlated with CIDI diagnoses of anxiety and depression.<sup>23</sup> Several study limitations should be noted. The follow-up period may have been too short to observe the full extent of long-term associations between fruit and vegetable intake and psychological distress. Although the assessment of fruit and vegetable consumption was based on short validated questions, this assessment method may be prone to reporting bias. In addition, the assessment of dietary intake was not detailed and limited to a few questions only. There may be residual confounding from unmeasured dietary confounders including total energy intake and other potential confounders such as illicit drug use, despite adjustment for multiple covariates. Although data was available for fish consumption, another potential dietary confounder, this variable was not included as a covariate due to the lack of variance observed (“yes/no” question for ever consumption of fish only) and adjusting for fish consumption in our analyses also did not change our results. Further, the possibility of reverse causation (i.e., that depression leads to poor diet including inadequate fruit

and vegetable consumption) could not be eliminated, but was reduced by excluding participants being treated for depression/anxiety, taking anti-depressant medication or who reported high-to-very levels of psychological distress at baseline from the longitudinal analyses. Several prospective cohort studies have not found evidence for reverse causation, with diet quality related to subsequent mental health but baseline mental health not associated with subsequent diet quality.<sup>14,16,20</sup>

## Conclusions

Fruit and vegetable consumption may help reduce the prevalence of psychological distress among middle-aged and older adults. However, the association between fruit and vegetable consumption and the incidence of psychological distress requires further investigation and possibly, a longer follow-up time. Findings from this study lend support to existing public health guidelines which encourage fruit and vegetable consumption as part of a healthy diet and add evidence to support the benefits of fruit and vegetables for mental health.

**ACKNOWLEDGEMENTS**

This research was completed using data collected through the 45 and Up Study ([www.saxinstitute.org.au/our-work/45-up-study/](http://www.saxinstitute.org.au/our-work/45-up-study/)). The 45 and Up Study is managed by the Sax Institute in collaboration with major partner Cancer Council NSW; and partners: the National Heart Foundation of Australia (NSW Division); NSW Ministry of Health; NSW Government Family and Community Services – Carers, Ageing, and Disability Inclusion; and the Australian Red Cross Blood Service. We thank the many thousands of people participating in the 45 and Up Study and the SEEF Study. The SEEF research was funded by the National Health and Medical Research Council (NHMRC) Strategic Award for Preventive Healthcare and Strengthening Australia’s Social Economic Fabric (The SEEF Project; ID: 402810).

## COMPETING INTERESTS

The authors declare that they have no competing interests.

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**FUNDING**

This research was funded from a Development Award from the Cardiovascular Research Network of NSW. BN was supported by an Australian Postgraduate Award and a University of Sydney Merit Award. DD (reference number 1072223) was funded by an Early Career Fellowship from the NHMRC of Australia.

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## AUTHORS' CONTRIBUTIONS

BN, DD and SM participated in the design of the study. BN carried out the statistical analyses. BN, DD and SM helped draft the manuscript. All authors helped with the interpretation of the data and revised the manuscript critically for important intellectual content. All authors read and approved the manuscript.

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**DATA SHARING STATEMENT**

No additional data are available.

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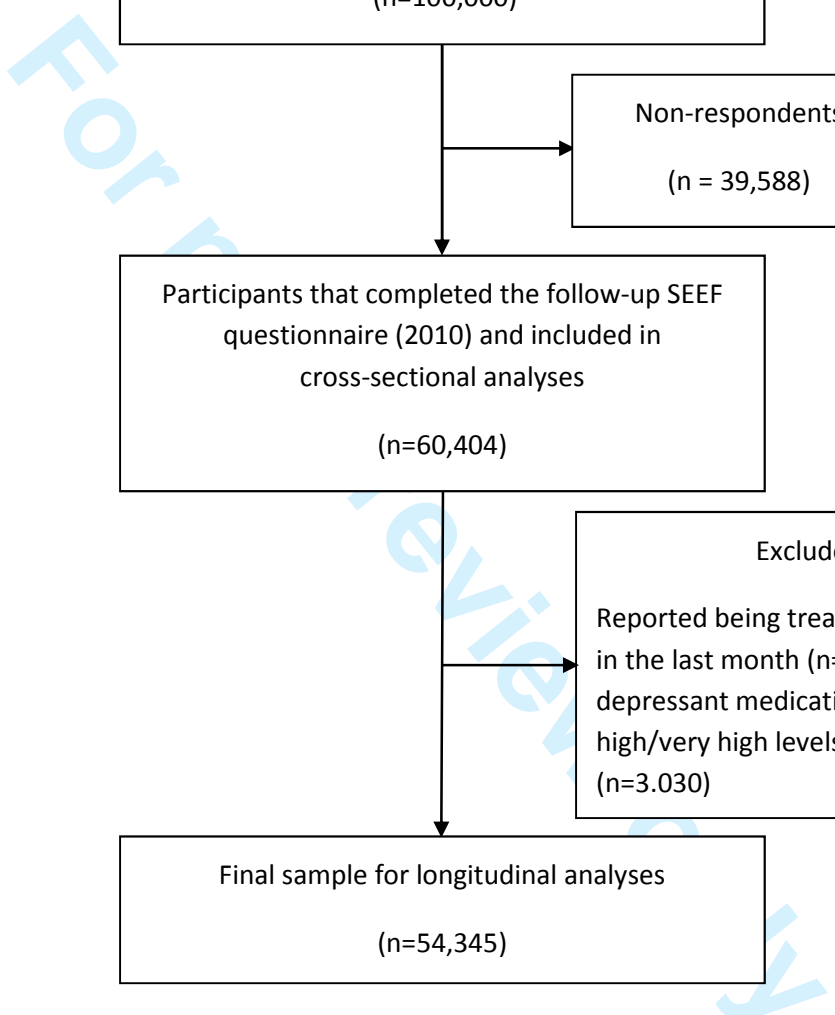


Fig. 1. Participant flow chart

**STROBE 2007 (v4) checklist of items to be included in reports of observational studies in epidemiology\***  
**Checklist for cohort, case-control, and cross-sectional studies (combined)**

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study’s design with a commonly used term in the title or the abstract	1, 3
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5
Objectives	3	State specific objectives, including any pre-specified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(a) Cohort study—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up Case-control study—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls Cross-sectional study—Give the eligibility criteria, and the sources and methods of selection of participants	6
		(b) Cohort study—For matched studies, give matching criteria and number of exposed and unexposed Case-control study—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-7
Bias	9	Describe any efforts to address potential sources of bias	6-8
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-8
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	8
		(b) Describe any methods used to examine subgroups and interactions	8
		(c) Explain how missing data were addressed	8
		(d) Cohort study—If applicable, explain how loss to follow-up was addressed Case-control study—If applicable, explain how matching of cases and controls was addressed	

		<i>Cross-sectional study</i> —If applicable, describe analytical methods taking account of sampling strategy	
		(e) Describe any sensitivity analyses	
<b>Results</b>			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	6
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9
		(b) Indicate number of participants with missing data for each variable of interest	8, 11
		(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)	9
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time	9
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure	
		<i>Cross-sectional study</i> —Report numbers of outcome events or summary measures	9
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	12-14
		(b) Report category boundaries when continuous variables were categorized	8
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9, 13, 15
<b>Discussion</b>			
Key results	18	Summarise key results with reference to study objectives	15
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	17
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	16-17
Generalisability	21	Discuss the generalisability (external validity) of the study results	
<b>Other information</b>			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	21

\*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at [www.strobe-statement.org](http://www.strobe-statement.org).

# BMJ Open

## Fruit and vegetable consumption and the prevalence and incidence of psychological distress in a large cohort of middle-aged and older Australians

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2016-014201.R1
Article Type:	Research
Date Submitted by the Author:	03-Nov-2016
Complete List of Authors:	Nguyen, Binh; THE UNIVERSITY OF SYDNEY, Prevention Research Collaboration Ding, Ding; University of Sydney, Prevention Research Collaboration, Sydney School of Public Health Mihirshahi, Seema; THE UNIVERSITY OF SYDNEY, Prevention Research Collaboration
<b>Primary Subject Heading</b>:	Mental health
Secondary Subject Heading:	Nutrition and metabolism
Keywords:	MENTAL HEALTH, NUTRITION & DIETETICS, Depression & mood disorders < PSYCHIATRY

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**Title**

Fruit and vegetable consumption and the prevalence and incidence of psychological distress in a large cohort of middle-aged and older Australians

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**4 Key words**

5 Fruit, vegetable, mental health, depression

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**ABSTRACT**

**Objectives.** Growing evidence suggests a link between diet and mental health. This study aimed to investigate the association between fruit and vegetable consumption and the prevalence and incidence of psychological distress in middle-aged and older Australians.

**Design.** Cross-sectional and prospective.

**Setting.** New South Wales, Australia.

**Methods.** A sample of 60,404 adults aged  $\geq 45$  years completed baseline (2006-2008) and follow-up (2010) questionnaires. Psychological distress was assessed at baseline and follow-up using the validated Kessler psychological distress (K10) scale, a 10-item questionnaire measuring general anxiety and depression. Psychological distress was defined as the presence of high-to-very high levels of distress (K10 score  $\geq 22$ ). Usual fruit and vegetable consumption was assessed using short validated questions. The association between baseline fruit and vegetable consumption and the prevalence or incidence of psychological distress was examined using logistic regression models.

**Results.** At baseline, 5.6% reported psychological distress. During a mean 2.7 years of follow-up, 4.0% of those who did not report distress at baseline reported distress at follow-up. Baseline fruit and vegetable consumption, considered separately or combined, was associated with a lower prevalence of psychological distress even after adjustment for socio-demographic characteristics and lifestyle risk factors. Baseline fruit and vegetable consumption, measured separately or combined, was associated with a lower incidence of psychological distress in minimally-adjusted models. Most of these associations remained significant at medium levels of intake but were no longer significant at the highest intake levels in fully-adjusted models.

**Conclusions.** Increasing fruit and vegetable consumption may help reduce psychological distress in middle-aged and older adults. However, the association of fruit and vegetable consumption with the incidence of psychological distress requires further investigation.

## STRENGTHS AND LIMITATIONS OF THIS STUDY

- This study included a large sample size of 60,404 participants for cross-sectional analyses and 54,345 participants for longitudinal analyses.
- Analyses were adjusted for multiple socio-demographic and lifestyle-related covariates.
- The well-validated Kessler psychological distress (K10) scale was used to assess psychological distress.
- The relatively short follow-up time may have been insufficient to observe the full extent of long-term associations between fruit and vegetable intake and psychological distress.

1 INTRODUCTION

2 There has been a global call for action by the World Health Organisation (WHO) to make mental  
3 health a global development priority.<sup>1</sup> Mental disorders affect a tenth of the world population and  
4 represent 30% of non-fatal global burden of disease.<sup>2</sup> Depression alone is a leading cause of  
5 disability worldwide<sup>3</sup> and is projected to rank among the three leading causes of global disease  
6 burden by 2030.<sup>4</sup> There is an urgent call for public health strategies aimed at preventing the  
7 onset on common mental disorders, such as depression.

8 There has been considerable interest in the relationship between psychological wellbeing and  
9 lifestyle factors, with growing evidence for a link between mental health and diet.<sup>5-7</sup> The role of  
10 fruit and vegetables has received increasing attention, given evidence for its protective effects  
11 against chronic diseases such as cardiovascular disease and cancer.<sup>8,9</sup> Diets low in fruit have  
12 been recently identified as the leading dietary risk factor for global burden of disease.<sup>10</sup>

13 Findings from a recent meta-analysis, based on seven cross-sectional and four prospective  
14 studies, suggest that both fruit and vegetable consumption are significantly associated with a  
15 lower risk of depression.<sup>11</sup> Several large cross-sectional studies have shown that greater  
16 consumption of fruit and vegetables is associated with better mental health, including lower  
17 odds of depression and psychological distress, in the general population.<sup>12-14</sup> Fewer studies  
18 have investigated the longitudinal association between fruit and vegetable intake and  
19 depression. Higher consumption of fruit and/or vegetables was associated with lower odds of  
20 incident depression in middle-aged Australian women followed over six years,<sup>15</sup> post-  
21 menopausal American women followed for three years<sup>16</sup> and Spanish adults followed over four  
22 years.<sup>17</sup> These findings are in agreement with previous cross-sectional and longitudinal studies  
23 that have found healthy dietary patterns, including high intakes of fruit and vegetables, to be  
24 associated with a lower risk of depression and anxiety, particularly in middle-aged and older  
25 adults.<sup>18-21</sup>

26 Depression in later life is associated with increased morbidity and mortality, and decreased  
27 physical, cognitive and social functioning.<sup>22</sup> Improving mental health is an important public  
28 health challenge to address in an ageing population with a higher life expectancy.<sup>1</sup> Therefore,  
29 the main objective of this study was to investigate the association between fruit and vegetable  
30 consumption and the prevalence and incidence of psychological distress in a large cohort of  
31 middle-aged and older Australians.

## METHODS

### Study population

The baseline data were from the Sax Institute's 45 and Up Study, a large-scale (n=267,153) population study of men and women aged 45 years and over, who were randomly sampled from the general population of New South Wales (NSW), Australia. From January 2006 to December 2008, eligible individuals joined the study by completing a postal questionnaire and providing written consent for participation and long-term follow-up. The 45 and Up Study has been described in detail elsewhere.<sup>23</sup> A subsample of the 45 and Up Study was followed-up in 2010 (i.e, the Social, Economic, and Environmental Factor [SEEF] Study), with the first 100,000 participants of the 45 and Up Study invited to complete the SEEF questionnaire (60.4% response rate). A participant flow chart for this study is provided in **Figure 1**. For cross-sectional analyses at baseline, the analytic sample included 60,404 participants (53.6% women). For longitudinal analyses, participants who reported on the baseline questionnaire that they had been treated for depression/anxiety in the last month (n=3,796), and/or taking anti-depressant medication for most of the last four weeks (n=700), and/or with high/very high levels of psychological distress (n=3,030; defined as having a Kessler psychological distress scale [K10] score $\geq 22$ <sup>24</sup> were excluded (n=6,067), leaving a final sample of 54,345 participants. The 45 and Up Study was granted ethical approval by the University of NSW Human Research Ethics Committee (reference HREC 05035/HREC 10186) and the SEEF Study by the University of Sydney Human Research Ethics Committee (reference 10-2009/12187).

### Measurement

The 45 and Up Study and SEEF Study questionnaires include questions on socio-demographic characteristics, personal and medical history, and lifestyle risk factors (available from <http://www.saxinstitute.org.au/our-work/45-up-study/questionnaires/>).

### Outcome

At both baseline and follow-up, participants' general level of psychological distress was assessed using the well-validated and widely used K10 scale, a 10-item questionnaire about anxiety and depression symptoms experienced in the last four weeks.<sup>24</sup> A five-point response scale (none of the time, a little of the time, some of the time, most of the time, all of the time) is used for each item, with scores ranging from 1 (none of the time) to 5 (all of the time). Scores to each question are added up to form the total K10 score, with a possible range of 10-50. For this study, score groupings and categories of psychological distress routinely used by the Australian

1 Bureau of Statistics for national health surveys were adopted with total scores of: 10-15, 16-21,  
2 22-29 and 30-50 indicating low, moderate, high and very high levels of psychological distress,  
3 respectively.

4 High K10 scores are strongly correlated with current WHO's Composite International Diagnostic  
5 Interview (CIDI) diagnosis of anxiety and affective disorders.<sup>24</sup> Prevalence of psychological  
6 distress at baseline was defined as the presence of high-to-very high levels of psychological  
7 distress (K10 score $\geq$ 22). Incidence of psychological distress was defined as: 1) not being  
8 treated for anxiety/depression in the last month, and/or not taking anti-depressant medication for  
9 most of the last four weeks, and/or not having high/very high levels of psychological distress  
10 (K10 score $<$ 22) at baseline, and 2) the presence of high-to-very high levels of psychological  
11 distress (K10 score $\geq$ 22) at follow-up. Psychological distress was treated as binary outcome  
12 variable in the analyses (K10 score $<$ 22 vs.  $\geq$ 22; i.e. low-to-moderate vs high-to-very high levels  
13 of distress).

14 Exposure

15 Usual fruit and vegetable consumption was assessed at baseline using the following validated  
16 short questions commonly used in health monitoring and surveillance.<sup>25</sup>

- 17 1. "About how many serves of fruit do you usually have each day?" One serve of fruit was  
18 defined as one medium piece or two small pieces of fresh fruit, or one cup of diced or  
19 canned fruit pieces.
- 20 2. "About how many serves of vegetables do you usually eat each day?" One serve of  
21 vegetables was defined as half a cup of cooked vegetables (including potatoes) or one  
22 cup of raw vegetables (e.g. salad).

23 Total fruit and vegetable consumption was derived by summing the reported number of fruit and  
24 vegetables consumed daily. Fruit and vegetable consumption, considered separately and  
25 combined, was categorised into tertiles. Using quantiles ensures that the range in exposure is  
26 captured evenly across distribution categories, which facilitates comparison between different  
27 levels of fruit and vegetable consumption among the study cohort, and has been previously  
28 used in another large cohort study.<sup>16</sup>

29 Covariates

30 Covariates included baseline self-reported socio-demographic characteristics such as sex, age,  
31 highest level of education ( $\leq$ 10 years of schooling, high school/trade

1 apprenticeship/certificate/diploma, university degree/higher), marital status (married/living with a  
2 partner vs. single/widowed/divorced/separated), household annual income (<\$30,000, \$30,000-  
3 \$69,999, ≥\$70,000, would rather not answer this question), self-reported history of major  
4 chronic disease (cancer other than non-melanoma skin cancer, cardiovascular disease [heart  
5 disease, stroke or blood clot], diabetes or hypertension; yes vs. no) and the following lifestyle  
6 risk factors: body mass index (BMI; derived from self-reported height and weight), alcohol intake  
7 (≤14 or >14 drinks/week), smoking status (current regular smoker vs. not currently a regular  
8 smoker) and physical activity levels (assessed using validated questions from the Active  
9 Australia Survey;<sup>26</sup> categorised as <150, 150-299 and ≥300 minutes/week).

### 10 **Statistical analysis**

11 The association between baseline fruit and vegetable consumption and the prevalence/  
12 incidence of psychological distress (K10 score ≥22) was examined using logistic regression  
13 models. Odds ratios (ORs) with 95% confidence intervals (CI) are presented for unadjusted,  
14 age- and sex- adjusted, and models adjusted for all covariates as described above. We tested  
15 effect modification by sex by fitting interaction terms. To examine potential sex differences, the  
16 analyses were further stratified by sex. If one out of ten responses to K10 scale questions was  
17 missing (for 3.2% and 2.8% of participants included in cross-sectional and longitudinal analyses  
18 respectively), the missing value was imputed using the mean score across the other nine  
19 questions.<sup>27</sup> If more than one response was missing, K10 scores were considered as missing.  
20 P-values <0.05 were considered statistically significant. All analyses were conducted using  
21 SPSS version 22 (IBM Corp., Armonk, NY).



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3 1 **RESULTS**  
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6 2 **Participant characteristics**  
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8 **Table 1** shows baseline participant characteristics based on K10 score at follow-up. Overall, the  
9 mean age (standard deviation [SD]) of participants was 62.2 (10.6) years, more than half  
10 (53.6%) were women, over a quarter (26%) had a university degree/higher, over three-quarters  
11 (78%) were in a married/de facto relationship, and a quarter (25.7%) reported a household  
12 annual income  $\geq$ \$70,000. The mean (SD) serves of fruit and vegetables were respectively 2.0  
13 (1.4) and 3.9 (2.6) serves/day. The average follow-up time period was 2.7 (0.9) years.  
14 Compared with men, women were more likely to be younger, less educated,  
15 single/widowed/divorced/separated, have a lower household annual income, a lower BMI, and  
16 to consume more fruit and vegetables and less alcohol. Participants with high-to-very high  
17 levels of psychological distress (5.6%) at baseline were more likely to be women, relatively  
18 younger, less educated and have a lower household annual income. These participants were  
19 also more likely to: have a higher BMI, be a current smoker, be less physically active and have  
20 a history of chronic disease.  
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29 16 **Prevalence of psychological distress**  
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31 The ORs for the association between separate or combined fruit and vegetable consumption  
32 and the prevalence of high-to-very high levels of psychological distress ( $K10 \geq 22$ ) are presented  
33 in **Table 2**. Consumption of fruit and vegetables, considered separately or combined, was  
34 consistently associated with a lower prevalence of psychological distress. Following adjustment  
35 for all covariates, these associations were slightly attenuated compared with the unadjusted  
36 model but remained significant. Other covariates which were significantly associated with the  
37 prevalence of psychological distress were being relatively younger,  
38 single/divorced/widowed/separated, a current smoker, lower education, lower household annual  
39 income, lower BMI, low physical activity levels and a self-reported history of chronic disease.  
40 There was a significant interaction between combined fruit and vegetable consumption and sex  
41 ( $p=0.049$ ). When analyses were stratified by sex (**Table 4**), the association between fruit and  
42 vegetable consumption, measured separately or combined, and the prevalence of psychological  
43 distress was markedly stronger in women and was significant for all consumption tertiles  
44 ( $p \leq 0.001$ ). Among men, only those in the medium tertiles of separate fruit and vegetable  
45 consumption had significantly lower odds of psychological distress.  
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56 32 **Incidence of psychological distress**  
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During an average of 2.7 years of follow-up, 4.0% of those who did not report distress at baseline reported distress at follow-up. **Table 3** shows the association between fruit and vegetable consumption and the incidence of high-to-very high levels of psychological distress ( $K10 \geq 22$ ). Similar to cross-sectional findings, fruit and vegetable consumption, measured separately or combined, was significantly associated with a lower incidence of psychological distress in both unadjusted and minimally-adjusted models. In the fully-adjusted models, the medium tertiles of both combined fruit and vegetable consumption, and separate vegetable consumption, remained significantly associated with reduced odds of psychological distress. The association between the medium tertile of fruit consumption and the incidence of psychological distress approached significance ( $p=0.07$ ). However, the association between the highest tertile of consumption and the incidence of psychological distress did not remain significant for consumption of fruit and vegetables considered either separately or combined. Other covariates which were significantly associated with the incidence of psychological distress were being relatively younger, single/divorced/widowed/separated, a current smoker, lower education, lower household annual income, lower alcohol intake, lower BMI, low physical activity levels and a self-reported history of chronic disease. There was a significant interaction between combined fruit and vegetable consumption and sex ( $p=0.08$ ). When analyses were stratified by sex (**Table 4**), the association between fruit and vegetable consumption, considered separately or combined, and the incidence of psychological distress was stronger in women and significant for all consumption tertiles except for the highest fruit ( $p=0.06$ ) and vegetable tertiles ( $p=0.17$ ). There was no significant association between consumption of fruit and vegetables and the incidence of psychological distress in men.

## DISCUSSION

In this large cohort of middle-aged and older Australian adults, consumption of fruit and vegetables was significantly associated with the prevalence of psychological distress even after accounting for socio-demographic characteristics and other lifestyle risk factors. The longitudinal associations with psychological distress were less consistent. The association between fruit and vegetable intake and the incidence of psychological distress was significant after accounting for age and sex. After adjustment for all possible confounders, while this association remained mostly significant at medium levels of intake, it did not remain significant at the highest levels of intake. When considered separately in each sex, the association of fruit and vegetable

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**Table 1.** Baseline characteristics of participants according to sex and K10 score at baseline (n=60,404; 2006-2010)<sup>a</sup>

Variable	All	Men	Women	K10 score at baseline <sup>b</sup>		
				<22	≥22	p-value <sup>d</sup>
Sample size	60,404	28,057	32,347	551,393	33,030	
Mean (SD) follow-up time (years)	2.67 (0.93)	2.67 (0.93)	2.68 (0.94)	2.67 (0.94)	2.72 (0.95)	0.009
Women (%)	53.6	-	-	53.3	56.2	<0.001
Mean (SD) age (years)	62.2 (10.6)	63.9 (10.7)	60.8 (10.2) <sup>c</sup>	661.6 (10.3)	658.6 (9.6)	<0.001
Highest education <sup>c</sup> (%)						<0.001
University and higher	26.2	28.0	24.7	28.3	20.0	
High school/trade apprenticeship/certificate/ Diploma	42.7	48.5	37.7	43.3	41.3	
≤10 years	31.1	23.4	37.6	28.4	468.1	
Married/living with a partner (%)	78.0	83.5	73.2 <sup>c</sup>	79.6	68.1	<0.001
Household annual income <sup>c</sup> (%)						<0.001
<\$30,000	29.5	28.5	30.4	26.7	43.4	

\$30,000-\$69,999	28.9	31.0	27.0	29.8	25.4	
≥\$70,000	25.7	29.3	22.6	28.1	16.7	
Did not specify	15.9	11.2	20.0	15.4	14.4	
BMI category <sup>c</sup> (%)						<0.001
Underweight (<18.5 kg/m <sup>2</sup> )	1.2	0.7	1.7	1.1	2.2	
Normal weight (18.5 to <25 kg/m <sup>2</sup> )	37.9	31.8	43.3	38.4	31.0	
Overweight or obese (≥25 kg/m <sup>2</sup> )	60.9	67.6	55.0	60.5	66.8	
Current smoker (%)	5.7	5.7	5.7	5.3	13.9	<0.001
Usually consumes >14 alcohol drinks/week	14.9	24.7	6.3 <sup>c</sup>	15.3	14.8	0.44
Mean (SD) fruit consumption (serves/day)	2.0 (1.4)	1.9 (1.5)	2.2 (1.4) <sup>c</sup>	2.0 (1.4)	1.9 (1.5)	<0.001
Mean (SD) vegetable consumption (serves/day)	3.9 (2.6)	3.4 (2.6)	4.4 (2.6) <sup>c</sup>	43.9 (2.6)	3.7 (2.7)	<0.001
Physical activity level (%)						<0.001
<150 minutes/week	18.9	19.2	18.8	17.5	28.0	
150 to 299 minutes/week	16.6	16.4	16.9	16.6	18.7	
≥300 minutes/week	64.4	64.5	64.4	65.9	53.4	

History of chronic disease (%)	51.8	56.5	47.8 <sup>c</sup>	50.9	54.0	<0.001
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Abbreviations: BMI=body mass index, K10=Kessler Psychological Distress Scale, SD=standard deviation.

<sup>a</sup> Data are presented as means (SD) or percentages (%).

<sup>b</sup> The total K10 score is based on a 10-item questionnaire about anxiety and depression symptoms experienced in the last four weeks.<sup>24</sup> Participants were grouped according to K10 scores and categorised as at “low-to-moderate risk” (K10<22) or at “high-to-very high risk” of psychological distress (≥22). K10 data was missing for n=5,981.

<sup>c</sup> Significantly different from men (all p<0.001).

<sup>d</sup> P-value from independent t-tests for continuous variables and from chi-square tests for categorical variables.

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**Table 2.** Unadjusted and adjusted odds ratios for the baseline association between fruit and vegetable consumption and the prevalence of high-to-very high levels of psychological distress (K10<sup>a</sup>≥22 vs. K10<sup>a</sup><22).

	Unadjusted OR (95% CI)	P-value	Age and sex-adjusted OR (95% CI)	P-value	Fully-adjusted OR <sup>b</sup> (95% CI)	P-value
<i>Tertiles</i>						
Fruit						
0-1 serve/day	1.0 (reference)		1.0 (reference)		1.0 (reference)	
>1-2 serves/day	0.66 (0.60, 0.72)	<0.001	0.65 (0.59, 0.71)	<0.001	0.72 (0.65, 0.80)	<0.001
>2 serves/day	0.71 (0.65, 0.78)	<0.001	0.72 (0.65, 0.79)	<0.001	0.87 (0.79, 0.97)	0.01
Vegetables						
0-2 serves/day	1.0 (reference)		1.0 (reference)		1.0 (reference)	
>2-4 serves/day	0.73 (0.66, 0.80)	<0.001	0.70 (0.64, 0.77)	<0.001	0.81 (0.73, 0.90)	<0.001
>4 serves/day	0.76 (0.70, 0.84)	<0.001	0.75 (0.68, 0.82)	<0.001	0.85 (0.76, 0.94)	<0.001
Fruit and vegetables						
0-4 serves/day	1.0 (reference)		1.0 (reference)		1.0 (reference)	
>4-7 serves/day	0.73 (0.67, 0.79)	<0.001	0.70 (0.64, 0.77)	<0.001	0.82 (0.74, 0.90)	<0.001
>7 serves/day	0.71 (0.64, 0.78)	<0.001	0.70 (0.63, 0.77)	<0.001	0.82 (0.74, 0.92)	0.001

Abbreviations: CI=confidence interval, K10=Kessler Psychological Distress Scale, OR=odds ratio.

<sup>a</sup> The total K10 score is based on a 10-item questionnaire about anxiety and depression symptoms experienced in the last four weeks.<sup>24</sup> Possible K10 scores range from 10-50 with scores≥22 indicating high-to-very-high levels of psychological distress.

<sup>b</sup> Adjusted for baseline age, sex, highest education level, marital status, household annual income, body mass index category, smoking status, alcohol intake, physical activity levels and a history of chronic disease.

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**Table 3.** Unadjusted and adjusted odds ratios for the incidence of high-to-very high levels of psychological distress (K10<sup>a</sup>≥22) by baseline fruit and vegetable consumption.

	Unadjusted OR (95% CI)	P-value	Age and sex-adjusted OR (95% CI)	P-value	Fully-adjusted OR <sup>b</sup> (95% CI)	P-value
<i>Tertiles</i>						
Fruit						
0-1 serve/day	1.0 (reference)		1.0 (reference)		1.0 (reference)	
>1-2 serves/day	0.80 (0.72, 0.89)	<0.001	0.79 (0.71, 0.88)	<0.001	0.89 (0.79, 1.01)	0.07
>2 serves/day	0.79 (0.70, 0.88)	<0.001	0.78 (0.69, 0.87)	<0.001	0.90 (0.79, 1.03)	0.11
Vegetables						
0-2 serves/day	1.0 (reference)		1.0 (reference)		1.0 (reference)	
>2-4 serves/day	0.77 (0.69, 0.86)	<0.001	0.76 (0.68, 0.85)	<0.001	0.88 (0.78, 0.99)	0.03
>4 serves/day	0.87 (0.78, 0.97)	0.01	0.85 (0.76, 0.95)	0.003	0.92 (0.81, 1.04)	0.16
Fruit and vegetables						
0-4 serves/day	1.0 (reference)		1.0 (reference)		1.0 (reference)	
>4-7 serves/day	0.77 (0.69, 0.85)	<0.001	0.75 (0.67, 0.83)	<0.001	0.86 (0.77, 0.97)	0.01
>7 serves/day	0.85 (0.76, 0.95)	0.005	0.82 (0.73, 0.93)	0.001	0.90 (0.79, 1.03)	0.12

Abbreviations: CI=confidence interval, K10=Kessler Psychological Distress Scale, OR=odds ratio.  
Participants who reported having been recently treated for depression/anxiety and/or taking antidepressant medication and/or with a K10<sup>a</sup> score ≥22 (n=6,067) at baseline were excluded from this analysis.  
<sup>a</sup> The total K10 score is based on a 10-item questionnaire about anxiety and depression symptoms experienced in the last four weeks.<sup>24</sup> Possible K10 scores range from 10-50 with scores≥22 indicating high-to-very-high levels of psychological distress.  
<sup>b</sup> Adjusted for baseline age, sex, highest education level, marital status, household annual income, body mass index category, smoking status, alcohol intake, physical activity levels and a history of chronic disease.

**Table 4.** Adjusted odds ratios for the prevalence and incidence of high-to-very high levels of psychological distress ( $K10^a \geq 22$  vs.  $K10^a < 22$ ) by baseline fruit and vegetable consumption and stratified by sex.

	Cross-sectional analysis											
	Male						Female					
	Unadjusted OR (95% CI)	P-value	Age-adjusted OR (95% CI)	P-value	Fully-adjusted OR <sup>b</sup> (95% CI)	P-value	Unadjusted OR (95% CI)	P-value	Age-adjusted OR (95% CI)	P-value	Fully-adjusted OR <sup>b</sup> (95% CI)	P-value
<i>Tertiles</i>												
<i>Fruit</i>												
0-1 serve/day	1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)	
>1-2 serves/day	0.69 (0.59, 0.79)	<0.001	0.71 (0.61, 0.82)	<0.001	0.78 (0.67, 0.91)	0.002	0.59 (0.52, 0.66)	<0.001	0.61 (0.54, 0.69)	<0.001	0.67 (0.59, 0.77)	<0.001
>2 serves/day	0.80 (0.69, 0.93)	0.003	0.83 (0.72, 0.96)	0.02	0.99 (0.84, 1.17)	0.95	0.61 (0.54, 0.68)	<0.001	0.65 (0.57, 0.73)	<0.001	0.79 (0.69, 0.91)	0.001
<i>Vegetables</i>												
0-2 serves/day	1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)	
>2-4 serves/day	0.70 (0.61, 0.80)	<0.001	0.71 (0.62, 0.82)	<0.001	0.80 (0.69, 0.93)	0.004	0.66 (0.59, 0.75)	<0.001	0.68 (0.60, 0.77)	<0.001	0.80 (0.70, 0.92)	0.001
>4 serves/day	0.82 (0.71, 0.95)	0.007	0.88 (0.76, 1.01)	0.07	0.91 (0.78, 1.06)	0.23	0.64 (0.57, 0.72)	<0.001	0.68 (0.60, 0.77)	<0.001	0.80 (0.70, 0.92)	0.001
<i>Fruit and vegetables</i>												
0-4 serves/day	1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)	
>4-7 serves/day	0.80 (0.70, 0.91)	0.001	0.82 (0.72, 0.94)	0.003	0.92 (0.80, 1.07)	0.28	0.60 (0.53, 0.67)	<0.001	0.62 (0.55, 0.70)	<0.001	0.73 (0.64, 0.83)	<0.001
>7 serves/day	0.79 (0.67, 0.93)	0.004	0.84 (0.72, 0.99)	0.04	0.91 (0.76, 1.09)	0.30	0.57 (0.50, 0.65)	<0.001	0.61 (0.54, 0.70)	<0.001	0.75 (0.65, 0.87)	<0.001
	Longitudinal analysis <sup>c</sup>											
	Male						Female					
	Unadjusted OR (95% CI)	P-value	Age-adjusted OR (95% CI)	P-value	Fully-adjusted OR <sup>b</sup> (95% CI)	P-value	Unadjusted OR (95% CI)	P-value	Age-adjusted OR (95% CI)	P-value	Fully-adjusted OR <sup>b</sup> (95% CI)	P-value
<i>Tertiles</i>												
<i>Fruit</i>												
0-1 serve/day	1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)	
>1-2 serves/day	0.87 (0.74, 1.02)	0.09	0.87 (0.74, 1.02)	0.09	0.95 (0.80, 1.13)	0.56	0.72 (0.62, 0.83)	<0.001	0.72 (0.62, 0.84)	<0.001	0.84 (0.71, 1.0)	0.04
>2	0.90 (0.75, 1.07)	0.21	0.89 (0.75, 1.07)	0.20	0.98 (0.81, 1.17)	0.85	0.68 (0.58, 0.80)	<0.001	0.69 (0.59, 0.80)	<0.001	0.84 (0.70, 1.0)	0.06

serves/day	1.06)		1.06)		1.19)		0.80)		0.81)			
Vegetables												
0-2 serves/day	1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)	
>2-4 serves/day	0.86 (0.73, 1.0)	0.05	0.85 (0.73, 1.0)	0.05	0.94 (0.79, 1.11)	0.45	0.67 (0.57, 0.78)	<0.001	0.67 (0.57, 0.78)	<0.001	0.82 (0.69, 0.98)	0.03
>4 serves/day	0.96 (0.81, 1.13)	0.59	0.95 (0.81, 1.12)	0.55	0.94 (0.78, 1.13)	0.51	0.75 (0.65, 0.87)	<0.001	0.76 (0.65, 0.88)	<0.001	0.89 (0.75, 1.05)	0.17
Fruit and vegetables												
0-4 serves/day	1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)	
>4-7 serves/day	0.88 (0.76, 1.03)	0.11	0.88 (0.76, 1.03)	0.11	0.98 (0.83, 1.16)	0.82	0.63 (0.55, 0.73)	<0.001	0.64 (0.55, 0.74)	<0.001	0.77 (0.65, 0.91)	0.002
>7 serves/day	0.96 (0.80, 1.14)	0.62	0.95 (0.79, 1.14)	0.57	0.94 (0.77, 1.15)	0.52	0.71 (0.61, 0.83)	<0.001	0.72 (0.62, 0.84)	<0.001	0.86 (0.72, 1.02)	0.09

Abbreviations: CI=confidence interval, K10=Kessler Psychological Distress Scale, OR=odds ratio.

<sup>a</sup> The total K10 score is based on a 10-item questionnaire about anxiety and depression symptoms experienced in the last four weeks.<sup>24</sup> Possible K10 scores range from 10-50 with scores≥22 indicating high-to-very-high levels of psychological distress.

<sup>b</sup> Adjusted for baseline age, sex, highest education level, marital status, household annual income, body mass index category, smoking status, alcoholic intake, physical activity levels and a history of chronic disease.

<sup>c</sup> Participants who reported having been recently treated for depression/anxiety and/or taking antidepressant medication and/or with a K10 score ≥22 (n=6,067) at baseline were excluded from longitudinal analyses.



consumption with either the prevalence or incidence of psychological distress was stronger in women, with no clear associations with the incidence of psychological distress in men.

Findings in this study are in agreement with those from a recent meta-analysis, based on seven cross-sectional and four cohort studies, which has found separate fruit and vegetable consumption to be inversely associated with the risk of depression.<sup>11</sup> Although findings from individual cross-sectional and prospective studies were mixed, in subgroup analysis by study design, the meta-analysis showed significant associations in both cross-sectional and prospective studies for fruit intake, and in prospective studies only for vegetable intake. In relation to combined fruit and vegetable consumption, several large cross-sectional studies have also demonstrated significant inverse associations with psychological wellbeing, even after accounting for multiple covariates.<sup>12-14</sup> A positive association between combined fruit and vegetable consumption and wellbeing, assessed using seven different measures of mental health, was shown in three separate data sets, which together involved 80,000 randomly selected British adults.<sup>12</sup> In a repeated cross-sectional study of 296,121 Canadians with five waves of a national, population-based survey, lower odds of depression and psychological distress were consistently associated with greater combined fruit and vegetable consumption.<sup>13</sup> Our cross-sectional findings are also in line with those from a recent population-based Swiss survey of 20,220 individuals, which found that daily recommended intake of five servings of fruit and vegetables was associated with a lower likelihood of high and moderate psychological distress.<sup>14</sup>

Our longitudinal findings add to the limited evidence base for an association between fruit and vegetable consumption and the incidence of psychological distress. Although longitudinal associations with psychological distress did not remain significant at higher levels of fruit and vegetable intake, the direction of these associations was in agreement with findings from previous studies. Among the few prospective studies which have examined the relationship between fruit and vegetable intake and the incidence of depression, mostly in similar-aged samples,<sup>15-17, 28</sup> all but one study<sup>28</sup> have shown significant protective effects of fruit<sup>15,17</sup> or both fruit and vegetables.<sup>16</sup> A recent study involving a nationally representative sample of 12,385 Australian adults surveyed over several years, reported that combined fruit and vegetable consumption was predictive of increased happiness, life satisfaction and wellbeing, with improvements observed within two years.<sup>29</sup> In our study, it is possible that longitudinal associations between higher fruit and vegetable consumption and psychological distress did not remain statistically significant in fully-adjusted models due to a relatively smaller sample of

1 individuals with high-to-very high levels of distress in higher consumption compared with lower  
2 consumption categories, despite the use of tertiles.

3 This study is among the first to report associations between fruit and vegetable consumption  
4 and psychological wellbeing separately for men and women. Sex was a significant effect  
5 modifier of the association between fruit and vegetable consumption and psychological distress.  
6 We found that fruit and vegetables were more protective for women than men, suggesting that  
7 women may be more responsive to the effects of fruit and vegetables. It is possible that there  
8 may be a true physiological difference between men and women, although a mechanism that  
9 could explain this difference remains unclear, or perhaps women more accurately report  
10 consumption of fruit and vegetables than men. However, these preliminary findings need to be  
11 confirmed by additional studies.

12 Although these remain to be elucidated, several mechanisms may underlie the relationship  
13 between high fruit and vegetable consumption and greater psychological wellbeing.<sup>30</sup> Fruit and  
14 vegetables are rich in micronutrients and phytochemicals that may help reduce oxidative stress  
15 and inflammation, processes that can have detrimental effects on mental health. For example,  
16 antioxidants such as vitamins C, E and polyphenols may help reduce oxidative stress while the  
17 mineral magnesium has been associated with lower levels of C-reactive protein, a marker of  
18 low-grade inflammation.<sup>30</sup> Deficiencies in B-vitamins such as folic acid (vitamin B9) have been  
19 associated with depression.<sup>31</sup> Low levels of these vitamins can cause high homocysteine levels  
20 which in turn can impair methylation processes involved in the synthesis and metabolism of  
21 neurotransmitters that may affect mood.<sup>32</sup>

22 **Strengths and limitations**

23 This study had several strengths including a large sample size, a prospective design and the  
24 inclusion of multiple socio-demographic and lifestyle-related covariates and the use of the well-  
25 validated K10 scale to assess psychological distress. High K10 scores are strongly correlated  
26 with CIDI diagnoses of anxiety and depression.<sup>24</sup> Several study limitations should be noted. The  
27 follow-up period may have been too short to observe the full extent of long-term associations  
28 between fruit and vegetable intake and psychological distress. Although the assessment of fruit  
29 and vegetable consumption was based on short validated questions, this assessment method  
30 may be prone to reporting bias. In addition, the assessment of dietary intake was not detailed  
31 and limited to a few questions only. There may be residual confounding from unmeasured  
32 dietary confounders including total energy intake and other potential confounders such as illicit

1 drug use, despite adjustment for multiple covariates. Although data was available for fish  
2 consumption, another potential dietary confounder, this variable was not included as a covariate  
3 due to the lack of variance observed ("yes/no" question for ever consumption of fish only) and  
4 adjusting for fish consumption in our analyses also did not change our results. Further, the  
5 possibility of reverse causation (i.e., that depression leads to poor diet including inadequate fruit  
6 and vegetable consumption) could not be eliminated, but was reduced by excluding participants  
7 being treated for depression/anxiety, taking anti-depressant medication or who reported high-to-  
8 very levels of psychological distress at baseline from the longitudinal analyses. Several  
9 prospective cohort studies have not found evidence for reverse causation, with diet quality  
10 related to subsequent mental health but baseline mental health not associated with subsequent  
11 diet quality.<sup>15,17,21</sup> However, a recent nationally representative longitudinal study of Canadians  
12 which explicitly tested reverse causation, showed that the association between fruit and  
13 vegetable consumption, other health behaviors and depressive symptoms are complex and bi-  
14 directional and warrants further investigation.<sup>33</sup>

## 15 Conclusions

16 Fruit and vegetable consumption may help reduce the prevalence of psychological distress  
17 among middle-aged and older adults. However, the association between fruit and vegetable  
18 consumption and the incidence of psychological distress requires further investigation and  
19 possibly, a longer follow-up time. Findings from this study lend support to existing public health  
20 guidelines which encourage fruit and vegetable consumption as part of a healthy diet and add  
21 evidence to support the benefits of fruit and vegetables for mental health.

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**ACKNOWLEDGEMENTS**

This research was completed using data collected through the 45 and Up Study ([www.saxinstitute.org.au/our-work/45-up-study/](http://www.saxinstitute.org.au/our-work/45-up-study/)). The 45 and Up Study is managed by the Sax Institute in collaboration with major partner Cancer Council NSW; and partners: the National Heart Foundation of Australia (NSW Division); NSW Ministry of Health; NSW Government Family and Community Services – Carers, Ageing, and Disability Inclusion; and the Australian Red Cross Blood Service. We thank the many thousands of people participating in the 45 and Up Study and the SEEF Study. The SEEF research was funded by the National Health and Medical Research Council (NHMRC) Strategic Award for Preventive Healthcare and Strengthening Australia’s Social Economic Fabric (The SEEF Project; ID: 402810).

## COMPETING INTERESTS

The authors declare that they have no competing interests.

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**FUNDING**

This research was funded from a Development Award from the Cardiovascular Research Network of NSW. BN was supported by an Australian Postgraduate Award and a University of Sydney Merit Award. DD was funded by an Early Career Fellowship from the National Health and Medical Research Council of Australia (reference number 1072223).

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## AUTHORS' CONTRIBUTIONS

BN, DD and SM participated in the design of the study. BN carried out the statistical analyses. BN, DD and SM helped draft the manuscript. All authors helped with the interpretation of the data and revised the manuscript critically for important intellectual content. All authors read and approved the manuscript.

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- 1    **DATA SHARING STATEMENT**
- 2    No additional data are available.

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Fig. 1. Participant flow chart

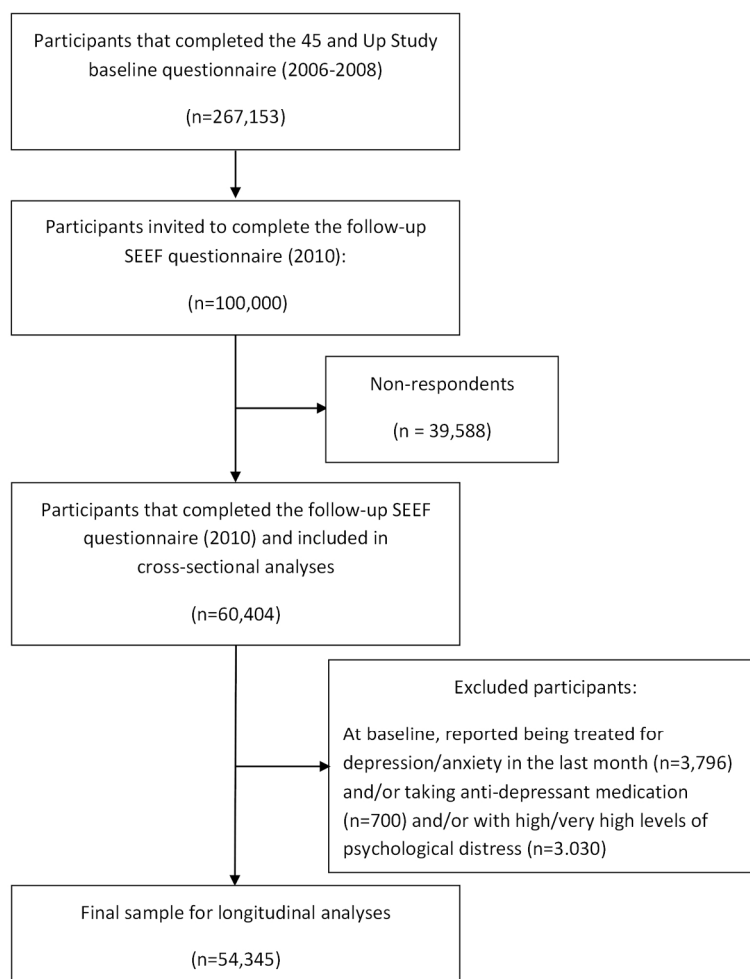


Fig. 1. Participant flow chart

173x197mm (300 x 300 DPI)

STROBE 2007 (v4) checklist of items to be included in reports of observational studies in epidemiology\*  
Checklist for cohort, case-control, and cross-sectional studies (combined)

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study’s design with a commonly used term in the title or the abstract	1, 3
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5
Objectives	3	State specific objectives, including any pre-specified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(a) Cohort study—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up Case-control study—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls Cross-sectional study—Give the eligibility criteria, and the sources and methods of selection of participants	6
		(b) Cohort study—For matched studies, give matching criteria and number of exposed and unexposed Case-control study—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-8
Bias	9	Describe any efforts to address potential sources of bias	6-8
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-8
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	8
		(b) Describe any methods used to examine subgroups and interactions	8
		(c) Explain how missing data were addressed	8
		(d) Cohort study—If applicable, explain how loss to follow-up was addressed Case-control study—If applicable, explain how matching of cases and controls was addressed	

		<i>Cross-sectional study</i> —If applicable, describe analytical methods taking account of sampling strategy	
		(e) Describe any sensitivity analyses	
<b>Results</b>			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	6, Figure 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9, Table 1
		(b) Indicate number of participants with missing data for each variable of interest	8, 13
		(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)	9
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time	10
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure	
		<i>Cross-sectional study</i> —Report numbers of outcome events or summary measures	9
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	14-17 (Tables 2-4)
		(b) Report category boundaries when continuous variables were categorized	7-8
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9-10, 16-17
<b>Discussion</b>			
Key results	18	Summarise key results with reference to study objectives	10, 18-20
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	19-20
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	10, 18-20
Generalisability	21	Discuss the generalisability (external validity) of the study results	
<b>Other information</b>			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	23

\*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at [www.strobe-statement.org](http://www.strobe-statement.org).

# BMJ Open

## Fruit and vegetable consumption and psychological distress: cross-sectional and longitudinal analyses based on a large Australian sample

Journal:	BMJ Open
Manuscript ID	bmjopen-2016-014201.R2
Article Type:	Research
Date Submitted by the Author:	29-Nov-2016
Complete List of Authors:	Nguyen, Binh; THE UNIVERSITY OF SYDNEY, Prevention Research Collaboration Ding, Ding; University of Sydney, Prevention Research Collaboration, Sydney School of Public Health Mihirshahi, Seema; THE UNIVERSITY OF SYDNEY, Prevention Research Collaboration
<b>Primary Subject Heading</b>:	Mental health
Secondary Subject Heading:	Nutrition and metabolism
Keywords:	MENTAL HEALTH, NUTRITION & DIETETICS, Depression & mood disorders < PSYCHIATRY

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**Title**

Fruit and vegetable consumption and psychological distress: cross-sectional and longitudinal analyses based on a large Australian sample

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**4 Key words**

5 Fruit, vegetable, mental health, depression

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**ABSTRACT**

**Objectives.** Growing evidence suggests a link between diet and mental health. This study aimed to investigate the association between fruit and vegetable consumption and the prevalence and incidence of psychological distress in middle-aged and older Australians.

**Design.** Cross-sectional and prospective.

**Setting.** New South Wales, Australia.

**Methods.** A sample of 60,404 adults aged  $\geq 45$  years completed baseline (2006-2008) and follow-up (2010) questionnaires. Psychological distress was assessed at baseline and follow-up using the validated Kessler psychological distress (K10) scale, a 10-item questionnaire measuring general anxiety and depression. Psychological distress was defined as the presence of high-to-very high levels of distress (K10 score  $\geq 22$ ). Usual fruit and vegetable consumption was assessed using short validated questions. The association between baseline fruit and vegetable consumption and the prevalence or incidence of psychological distress was examined using logistic regression models.

**Results.** At baseline, 5.6% reported psychological distress. After a mean 2.7 years of follow-up, 4.0% of those who did not report distress at baseline reported distress at follow-up. Baseline fruit and vegetable consumption, considered separately or combined, was associated with a lower prevalence of psychological distress even after adjustment for socio-demographic characteristics and lifestyle risk factors. Baseline fruit and vegetable consumption, measured separately or combined, was associated with a lower incidence of psychological distress in minimally-adjusted models. Most of these associations remained significant at medium levels of intake but were no longer significant at the highest intake levels in fully-adjusted models.

**Conclusions.** Increasing fruit and vegetable consumption may help reduce psychological distress in middle-aged and older adults. However, the association of fruit and vegetable consumption with the incidence of psychological distress requires further investigation.

## STRENGTHS AND LIMITATIONS OF THIS STUDY

- This study included a large sample size of 60,404 participants for cross-sectional analyses and 54,345 participants for longitudinal analyses.
- Analyses were adjusted for multiple socio-demographic and lifestyle-related covariates.
- The well-validated Kessler psychological distress (K10) scale was used to assess psychological distress.
- The relatively short follow-up time may have been insufficient to observe the full extent of long-term associations between fruit and vegetable intake and psychological distress.

1 INTRODUCTION

2 There has been a global call for action by the World Health Organisation (WHO) to make mental  
3 health a global development priority.<sup>1</sup> Mental disorders affect a tenth of the world population and  
4 represent 30% of non-fatal global burden of disease.<sup>2</sup> Depression alone is a leading cause of  
5 disability worldwide<sup>3</sup> and is projected to rank among the three leading causes of global disease  
6 burden by 2030.<sup>4</sup> There is an urgent call for public health strategies aimed at preventing the  
7 onset on common mental disorders, such as depression.

8 There has been considerable interest in the relationship between psychological wellbeing and  
9 lifestyle factors, with growing evidence for a link between mental health and diet.<sup>5-7</sup> The role of  
10 fruit and vegetables has received increasing attention, given evidence for its protective effects  
11 against chronic diseases such as cardiovascular disease and cancer.<sup>8,9</sup> Diets low in fruit have  
12 been recently identified as the leading dietary risk factor for global burden of disease.<sup>10</sup>

13 Findings from a recent meta-analysis, based on seven cross-sectional and four prospective  
14 studies, suggest that both fruit and vegetable consumption are significantly associated with a  
15 lower risk of depression.<sup>11</sup> Several large cross-sectional studies have shown that greater  
16 consumption of fruit and vegetables is associated with better mental health, including lower  
17 odds of depression and psychological distress, in the general population.<sup>12-14</sup> Fewer studies  
18 have investigated the longitudinal association between fruit and vegetable intake and  
19 depression. Higher consumption of fruit and/or vegetables was associated with lower odds of  
20 incident depression in middle-aged Australian women followed over six years,<sup>15</sup> post-  
21 menopausal American women followed for three years<sup>16</sup> and Spanish adults followed over four  
22 years.<sup>17</sup> These findings are in agreement with previous cross-sectional and longitudinal studies  
23 that have found healthy dietary patterns, including high intakes of fruit and vegetables, to be  
24 associated with a lower risk of depression and anxiety, particularly in middle-aged and older  
25 adults.<sup>18-21</sup>

26 Depression in later life is associated with increased morbidity and mortality, and decreased  
27 physical, cognitive and social functioning.<sup>22</sup> Improving mental health is an important public  
28 health challenge to address in an ageing population with a higher life expectancy.<sup>1</sup> Therefore,  
29 the main objective of this study was to investigate the association between fruit and vegetable  
30 consumption and the prevalence and incidence of psychological distress in a large cohort of  
31 middle-aged and older Australians.

## METHODS

### Study population

The baseline data were from the Sax Institute's 45 and Up Study, a large-scale (n=267,153) population study of men and women aged 45 years and over, who were randomly sampled from the general population of New South Wales (NSW), Australia. From January 2006 to December 2008, eligible individuals joined the study by completing a postal questionnaire and providing written consent for participation and long-term follow-up. The 45 and Up Study has been described in detail elsewhere.<sup>23</sup> A subsample of the 45 and Up Study was followed-up in 2010 (i.e, the Social, Economic, and Environmental Factor [SEEF] Study), with the first 100,000 participants of the 45 and Up Study invited to complete the SEEF questionnaire (60.4% response rate). A participant flow chart for this study is provided in **Figure 1**. For cross-sectional analyses at baseline, the analytic sample included 60,404 participants (53.6% women). For longitudinal analyses, participants who reported on the baseline questionnaire that they had been treated for depression/anxiety in the last month (n=3,796), and/or taking anti-depressant medication for most of the last four weeks (n=700), and/or with high/very high levels of psychological distress (n=3,030; defined as having a Kessler psychological distress scale [K10] score $\geq 22$ <sup>24</sup> were excluded (n=6,067), leaving a final sample of 54,345 participants. The 45 and Up Study was granted ethical approval by the University of NSW Human Research Ethics Committee (reference HREC 05035/HREC 10186) and the SEEF Study by the University of Sydney Human Research Ethics Committee (reference 10-2009/12187).

### Measurement

The 45 and Up Study and SEEF Study questionnaires include questions on socio-demographic characteristics, personal and medical history, and lifestyle risk factors (available from <http://www.saxinstitute.org.au/our-work/45-up-study/questionnaires/>).

### Outcome

At both baseline and follow-up, participants' general level of psychological distress was assessed using the well-validated and widely used K10 scale, a 10-item questionnaire about anxiety and depression symptoms experienced in the last four weeks.<sup>24</sup> A five-point response scale (none of the time, a little of the time, some of the time, most of the time, all of the time) is used for each item, with scores ranging from 1 (none of the time) to 5 (all of the time). Scores to each question are added up to form the total K10 score, with a possible range of 10-50. For this study, score groupings and categories of psychological distress routinely used by the Australian

1 Bureau of Statistics for national health surveys were adopted with total scores of: 10-15, 16-21,  
2 22-29 and 30-50 indicating low, moderate, high and very high levels of psychological distress,  
3 respectively.

4 High K10 scores are strongly correlated with current WHO's Composite International Diagnostic  
5 Interview (CIDI) diagnosis of anxiety and affective disorders.<sup>24</sup> Prevalence of psychological  
6 distress at baseline was defined as the presence of high-to-very high levels of psychological  
7 distress (K10 score $\geq$ 22). Incidence of psychological distress was defined as: 1) not being  
8 treated for anxiety/depression in the last month, and/or not taking anti-depressant medication for  
9 most of the last four weeks, and/or not having high/very high levels of psychological distress  
10 (K10 score $<$ 22) at baseline, and 2) the presence of high-to-very high levels of psychological  
11 distress (K10 score $\geq$ 22) at follow-up. Psychological distress was treated as binary outcome  
12 variable in the analyses (K10 score $<$ 22 vs.  $\geq$ 22; i.e. low-to-moderate vs high-to-very high levels  
13 of distress).

14 Exposure

15 Usual fruit and vegetable consumption was assessed at baseline using the following validated  
16 short questions commonly used in health monitoring and surveillance.<sup>25</sup>

- 17 1. "About how many serves of fruit do you usually have each day?" One serve of fruit was  
18 defined as one medium piece or two small pieces of fresh fruit, or one cup of diced or  
19 canned fruit pieces.
- 20 2. "About how many serves of vegetables do you usually eat each day?" One serve of  
21 vegetables was defined as half a cup of cooked vegetables (including potatoes) or one  
22 cup of raw vegetables (e.g. salad).

23 Total fruit and vegetable consumption was derived by summing the reported number of fruit and  
24 vegetables consumed daily. Fruit and vegetable consumption, considered separately and  
25 combined, was categorised into tertiles. Using quantiles ensures that the range in exposure is  
26 captured evenly across distribution categories, which facilitates comparison between different  
27 levels of fruit and vegetable consumption among the study cohort, and has been previously  
28 used in another large cohort study.<sup>16</sup>

29 Covariates

30 Covariates included baseline self-reported socio-demographic characteristics such as sex, age,  
31 highest level of education ( $\leq$ 10 years of schooling, high school/trade

apprenticeship/certificate/diploma, university degree/higher), marital status (married/living with a partner vs. single/widowed/divorced/separated), household annual income (<\$30,000, \$30,000-\$69,999, ≥\$70,000, would rather not answer this question), self-reported history of major chronic disease (cancer other than non-melanoma skin cancer, cardiovascular disease [heart disease, stroke or blood clot], diabetes or hypertension; yes vs. no) and the following lifestyle risk factors: body mass index (BMI; derived from self-reported height and weight; defined as underweight [ $<18.5 \text{ kg/m}^2$ ], normal weight [ $18.5\text{--}25 \text{ kg/m}^2$ ], overweight/obese [ $\geq 25 \text{ kg/m}^2$ ]), alcohol intake ( $\leq 14$  or  $>14$  drinks/week), smoking status (current regular smoker vs. not currently a regular smoker) and physical activity levels (assessed using validated questions from the Active Australia Survey,<sup>26</sup> categorised as  $<150$ , 150-299 and  $\geq 300$  minutes/week).

### Statistical analysis

The association between baseline fruit and vegetable consumption and the prevalence/incidence of psychological distress (K10 score  $\geq 22$ ) was examined using logistic regression models. Odds ratios (ORs) with 95% confidence intervals (CI) are presented for unadjusted, age- and sex- adjusted, and models adjusted for all covariates as described above. We tested effect modification by sex by fitting interaction terms. To examine potential sex differences, the analyses were further stratified by sex. If one out of ten responses to K10 scale questions was missing (for 3.2% and 2.8% of participants included in cross-sectional and longitudinal analyses respectively), the missing value was imputed using the mean score across the other nine questions.<sup>27</sup> If more than one response was missing, K10 scores were considered as missing. P-values  $<0.05$  were considered statistically significant. All analyses were conducted using SPSS version 22 (IBM Corp., Armonk, NY).



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3 1 **RESULTS**  
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6 2 **Participant characteristics**  
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8 **Table 1** shows baseline participant characteristics based on K10 score at follow-up. Overall, the  
9 mean age (standard deviation [SD]) of participants was 62.2 (10.6) years, more than half  
10 (53.6%) were women, over a quarter (26%) had a university degree/higher, over three-quarters  
11 (78%) were in a married/de facto relationship, and a quarter (25.7%) reported a household  
12 annual income  $\geq$ \$70,000. The mean (SD) serves of fruit and vegetables were respectively 2.0  
13 (1.4) and 3.9 (2.6) serves/day. The average follow-up time period was 2.7 (0.9) years.  
14 Compared with men, women were more likely to be younger, less educated,  
15 single/widowed/divorced/separated, have a lower household annual income, a lower BMI, and  
16 to consume more fruit and vegetables and less alcohol. Participants with high-to-very high  
17 levels of psychological distress (5.6%) at baseline were more likely to be women, relatively  
18 younger, less educated and have a lower household annual income. These participants were  
19 also more likely to: have a higher BMI, be a current smoker, be less physically active and have  
20 a history of chronic disease.  
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29 16 **Prevalence of psychological distress**  
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31 The ORs for the association between separate or combined fruit and vegetable consumption  
32 and the prevalence of high-to-very high levels of psychological distress ( $K10 \geq 22$ ) are presented  
33 in **Table 2**. Consumption of fruit and vegetables, considered separately or combined, was  
34 consistently associated with a lower prevalence of psychological distress. Following adjustment  
35 for all covariates, these associations were slightly attenuated compared with the unadjusted  
36 model but remained significant. Other covariates which were significantly associated with the  
37 prevalence of psychological distress were being relatively younger,  
38 single/divorced/widowed/separated, a current smoker, lower education, lower household annual  
39 income, lower BMI, low physical activity levels and a self-reported history of chronic disease.  
40 There was a significant interaction between combined fruit and vegetable consumption and sex  
41 ( $p=0.049$ ). When analyses were stratified by sex (**Table 4**), the association between fruit and  
42 vegetable consumption, measured separately or combined, and the prevalence of psychological  
43 distress was markedly stronger in women and was significant for all consumption tertiles  
44 ( $p \leq 0.001$ ). Among men, only those in the medium tertiles of separate fruit and vegetable  
45 consumption had significantly lower odds of psychological distress.  
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56 32 **Incidence of psychological distress**  
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After an average of 2.7 years of follow-up, 4.0% of those who did not report distress at baseline reported distress at follow-up. **Table 3** shows the association between fruit and vegetable consumption and the incidence of high-to-very high levels of psychological distress ( $K10 \geq 22$ ). Similar to cross-sectional findings, fruit and vegetable consumption, measured separately or combined, was significantly associated with a lower incidence of psychological distress in both unadjusted and minimally-adjusted models. In the fully-adjusted models, the medium tertiles of both combined fruit and vegetable consumption, and separate vegetable consumption, remained significantly associated with reduced odds of psychological distress. The association between the medium tertile of fruit consumption and the incidence of psychological distress approached significance ( $p=0.07$ ). However, the association between the highest tertile of consumption and the incidence of psychological distress did not remain significant for consumption of fruit and vegetables considered either separately or combined. Other covariates which were significantly associated with the incidence of psychological distress were being relatively younger, single/divorced/widowed/separated, a current smoker, lower education, lower household annual income, lower alcohol intake, lower BMI, low physical activity levels and a self-reported history of chronic disease. The interaction between combined fruit and vegetable consumption and sex approached significance ( $p=0.08$ ). When analyses were stratified by sex (**Table 4**), the association between fruit and vegetable consumption, considered separately or combined, and the incidence of psychological distress was stronger in women and significant for all consumption tertiles except for the highest fruit ( $p=0.06$ ), vegetable ( $p=0.17$ ), and combined fruit and vegetable tertiles ( $p=0.09$ ) in the fully-adjusted models. There was no significant association between consumption of fruit and vegetables and the incidence of psychological distress in men.

## DISCUSSION

In this large cohort of middle-aged and older Australian adults, consumption of fruit and vegetables was significantly associated with the prevalence of psychological distress even after accounting for socio-demographic characteristics and other lifestyle risk factors. The longitudinal associations with psychological distress were less consistent. The association between fruit and vegetable intake and the incidence of psychological distress was significant after accounting for age and sex. After adjustment for all possible confounders, while this association remained mostly significant at medium levels of intake, it did not remain significant at the highest levels of intake. When considered separately in each sex, the association of fruit and vegetable

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**Table 1.** Baseline characteristics of participants according to sex and K10 score at baseline (n=60,404; 2006-2010)<sup>a</sup>

Variable	All	Men	Women	K10 score at baseline <sup>b</sup>		
				<22	≥22	p-value <sup>d</sup>
Sample size	60,404	28,057	32,347	51,393	3,030	
Mean (SD) follow-up time (years)	2.67 (0.93)	2.67 (0.93)	2.68 (0.94)	2.67 (0.94)	2.72 (0.95)	0.009
Women (%)	53.6	-	-	53.3	56.2	<0.001
Mean (SD) age (years)	62.2 (10.6)	63.9 (10.7)	60.8 (10.2) <sup>c</sup>	61.6 (10.3)	58.6 (9.6)	<0.001
Highest education <sup>c</sup> (%)						<0.001
University and higher	26.2	28.0	24.7	28.3	20.0	
High school/trade apprenticeship/certificate/ Diploma	42.7	48.5	37.7	43.3	41.3	
≤10 years	31.1	23.4	37.6	28.4	68.1	
Married/living with a partner (%)	78.0	83.5	73.2 <sup>c</sup>	79.6	68.1	<0.001
Household annual income <sup>c</sup> (%)						<0.001
<\$30,000	29.5	28.5	30.4	26.7	43.4	

\$30,000-\$69,999	28.9	31.0	27.0	29.8	25.4	
≥\$70,000	25.7	29.3	22.6	28.1	16.7	
Did not specify	15.9	11.2	20.0	15.4	14.4	
BMI category <sup>c</sup> (%)						<0.001
Underweight (<18.5 kg/m <sup>2</sup> )	1.2	0.7	1.7	1.1	2.2	
Normal weight (18.5 to <25 kg/m <sup>2</sup> )	37.9	31.8	43.3	38.4	31.0	
Overweight or obese (≥25 kg/m <sup>2</sup> )	60.9	67.6	55.0	60.5	66.8	
Current smoker (%)	5.7	5.7	5.7	5.3	13.9	<0.001
Usually consumes >14 alcohol drinks/week	14.9	24.7	6.3 <sup>c</sup>	15.3	14.8	0.44
Mean (SD) fruit consumption (serves/day)	2.0 (1.4)	1.9 (1.5)	2.2 (1.4) <sup>c</sup>	2.0 (1.4)	1.9 (1.5)	<0.001
Mean (SD) vegetable consumption (serves/day)	3.9 (2.6)	3.4 (2.6)	4.4 (2.6) <sup>c</sup>	3.9 (2.6)	3.7 (2.7)	<0.001
Physical activity level (%)						<0.001
<150 minutes/week	18.9	19.2	18.8	17.5	28.0	
150 to 299 minutes/week	16.6	16.4	16.9	16.6	18.7	
≥300 minutes/week	64.4	64.5	64.4	65.9	53.4	

History of chronic disease (%)	51.8	56.5	47.8 <sup>c</sup>	50.9	54.0	<0.001
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Abbreviations: BMI=body mass index, K10=Kessler Psychological Distress Scale, SD=standard deviation.

<sup>a</sup> Data are presented as means (SD) or percentages (%).

<sup>b</sup> The total K10 score is based on a 10-item questionnaire about anxiety and depression symptoms experienced in the last four weeks.<sup>24</sup> Participants were grouped according to K10 scores and categorised as at “low-to-moderate risk” (K10<22) or at “high-to-very high risk” of psychological distress (≥22). K10 data was missing for n=5,981.

<sup>c</sup> Significantly different from men (all p<0.001).

<sup>d</sup> P-value from independent t-tests for continuous variables and from chi-square tests for categorical variables.

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**Table 2.** Unadjusted and adjusted odds ratios for the baseline association between fruit and vegetable consumption and the prevalence of high-to-very high levels of psychological distress (K10<sup>a</sup>≥22 vs. K10<sup>a</sup><22; n=60,404).

	Incident/total number of cases	Unadjusted OR (95% CI)	P-value	Age and sex-adjusted OR (95% CI)	P-value	Fully-adjusted OR <sup>b</sup> (95% CI)	P-value
<i>Tertiles</i>							
<i>Fruit<sup>c</sup></i>							
0-1 serve/day	1,394/21,767	1.0 (reference)		1.0 (reference)		1.0 (reference)	
>1-2 serves/day	891/19,538	0.66 (0.60, 0.72)	<0.001	0.65 (0.59, 0.71)	<0.001	0.72 (0.65, 0.80)	<0.001
>2 serves/day	753/16254	0.71 (0.65, 0.78)	<0.001	0.72 (0.65, 0.79)	<0.001	0.87 (0.79, 0.97)	0.01
<i>Vegetables<sup>c</sup></i>							
0-2 serves/day	1,277/16,694	1.0 (reference)		1.0 (reference)		1.0 (reference)	
>2-4 serves/day	919/15,560	0.73 (0.66, 0.80)	<0.001	0.70 (0.64, 0.77)	<0.001	0.81 (0.73, 0.90)	<0.001
>4 serves/day	968/15,023	0.76 (0.70, 0.84)	<0.001	0.75 (0.68, 0.82)	<0.001	0.85 (0.76, 0.94)	<0.001
<i>Fruit and vegetables<sup>c</sup></i>							
0-4 serves/day	1,374/22,387	1.0 (reference)		1.0 (reference)		1.0 (reference)	
>4-7 serves/day	1,068/21,750	0.73 (0.67, 0.79)	<0.001	0.70 (0.64, 0.77)	<0.001	0.82 (0.74, 0.90)	<0.001
>7 serves/day	702/14,974	0.71 (0.64, 0.78)	<0.001	0.70 (0.63, 0.77)	<0.001	0.82 (0.74, 0.92)	0.001

Abbreviations: CI=confidence interval, K10=Kessler Psychological Distress Scale, OR=odds ratio.

<sup>a</sup> The total K10 score is based on a 10-item questionnaire about anxiety and depression symptoms experienced in the last four weeks.<sup>24</sup> Possible K10 scores range from 10-50 with scores≥22 indicating high-to-very-high levels of psychological distress.

<sup>b</sup> Adjusted for baseline age, sex, highest education level, marital status, household annual income, body mass index category, smoking status, alcohol intake, physical activity levels and a history of chronic disease.

<sup>c</sup> There were missing cases for consumption of fruit (n=3,037), vegetables (n=1,190) and combined fruit and vegetables (n=1,293).

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**Table 3.** Unadjusted and adjusted odds ratios for the incidence of high-to-very high levels of psychological distress (K10<sup>a</sup>≥22) by baseline fruit and vegetable consumption (n=54,345<sup>b</sup>).

	Incident/total number of cases	Unadjusted OR (95% CI)	P-value	Age and sex-adjusted OR (95% CI)	P-value	Fully-adjusted OR <sup>c</sup> (95% CI)	P-value
<i>Tertiles</i>							
Fruit <sup>d</sup>							
0-1 serve/day	666/19,333	1.0 (reference)		1.0 (reference)		1.0 (reference)	
>1-2 serves/day	510/17,790	0.80 (0.72, 0.89)	<0.001	0.79 (0.71, 0.88)	<0.001	0.89 (0.79, 1.01)	0.07
>2 serves/day	407/14,724	0.79 (0.70, 0.88)	<0.001	0.78 (0.69, 0.87)	<0.001	0.90 (0.79, 1.03)	0.11
Vegetables <sup>d</sup>							
0-2 serves/day	641/18,898	1.0 (reference)		1.0 (reference)		1.0 (reference)	
>2-4 serves/day	486/17,281	0.77 (0.69, 0.86)	<0.001	0.76 (0.68, 0.85)	<0.001	0.88 (0.78, 0.99)	0.03
>4 serves/day	511/17,103	0.87 (0.78, 0.97)	0.01	0.85 (0.76, 0.95)	0.003	0.92 (0.81, 1.04)	0.16
Fruit and vegetables <sup>d</sup>							
0-4 serves/day	687/19,988	1.0 (reference)		1.0 (reference)		1.0 (reference)	
>4-7 serves/day	548/19,671	0.77 (0.69, 0.85)	<0.001	0.75 (0.67, 0.83)	<0.001	0.86 (0.77, 0.97)	0.01
>7 serves/day	396/13,560	0.85 (0.76, 0.95)	0.005	0.82 (0.73, 0.93)	0.001	0.90 (0.79, 1.03)	0.12

Abbreviations: CI=confidence interval, K10=Kessler Psychological Distress Scale, OR=odds ratio.

<sup>a</sup> The total K10 score is based on a 10-item questionnaire about anxiety and depression symptoms experienced in the last four weeks.<sup>24</sup> Possible K10 scores range from 10-50 with scores≥22 indicating high-to-very-high levels of psychological distress.

<sup>b</sup> Participants who reported having been recently treated for depression/anxiety and/or taking antidepressant medication and/or with a K10<sup>a</sup> score ≥22 (n=6,067) at baseline were excluded from this analysis.

<sup>c</sup> Adjusted for baseline age, sex, highest education level, marital status, household annual income, body mass index category, smoking status, alcohol intake, physical activity levels and a history of chronic disease.

<sup>d</sup> There were missing cases for consumption of fruit (n=2,498), vegetables (n=1,063) and combined fruit and vegetables (n=1,126).

**Table 4.** Adjusted odds ratios for the prevalence and incidence of high-to-very high levels of psychological distress ( $K10^a \geq 22$  vs.  $K10^a < 22$ ) by baseline fruit and vegetable consumption and stratified by sex.

	Cross-sectional analysis											
	Male						Female					
	Unadjusted OR (95% CI)	P-value	Age-adjusted OR (95% CI)	P-value	Fully-adjusted OR <sup>b</sup> (95% CI)	P-value	Unadjusted OR (95% CI)	P-value	Age-adjusted OR (95% CI)	P-value	Fully-adjusted OR <sup>b</sup> (95% CI)	P-value
<i>Tertiles</i>												
<i>Fruit</i>												
0-1 serve/day	1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)	
>1-2 serves/day	0.69 (0.59, 0.79)	<0.001	0.71 (0.61, 0.82)	<0.001	0.78 (0.67, 0.91)	0.002	0.59 (0.52, 0.66)	<0.001	0.61 (0.54, 0.69)	<0.001	0.67 (0.59, 0.77)	<0.001
>2 serves/day	0.80 (0.69, 0.93)	0.003	0.83 (0.72, 0.96)	0.02	0.99 (0.84, 1.17)	0.95	0.61 (0.54, 0.68)	<0.001	0.65 (0.57, 0.73)	<0.001	0.79 (0.69, 0.91)	0.001
<i>Vegetables</i>												
0-2 serves/day	1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)	
>2-4 serves/day	0.70 (0.61, 0.80)	<0.001	0.71 (0.62, 0.82)	<0.001	0.80 (0.69, 0.93)	0.004	0.66 (0.59, 0.75)	<0.001	0.68 (0.60, 0.77)	<0.001	0.80 (0.70, 0.92)	0.001
>4 serves/day	0.82 (0.71, 0.95)	0.007	0.88 (0.76, 1.01)	0.07	0.91 (0.78, 1.06)	0.23	0.64 (0.57, 0.72)	<0.001	0.68 (0.60, 0.77)	<0.001	0.80 (0.70, 0.92)	0.001
<i>Fruit and vegetables</i>												
0-4 serves/day	1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)	
>4-7 serves/day	0.80 (0.70, 0.91)	0.001	0.82 (0.72, 0.94)	0.003	0.92 (0.80, 1.07)	0.28	0.60 (0.53, 0.67)	<0.001	0.62 (0.55, 0.70)	<0.001	0.73 (0.64, 0.83)	<0.001
>7 serves/day	0.79 (0.67, 0.93)	0.004	0.84 (0.72, 0.99)	0.04	0.91 (0.76, 1.09)	0.30	0.57 (0.50, 0.65)	<0.001	0.61 (0.54, 0.70)	<0.001	0.75 (0.65, 0.87)	<0.001
	Longitudinal analysis <sup>c</sup>											
	Male						Female					
	Unadjusted OR (95% CI)	P-value	Age-adjusted OR (95% CI)	P-value	Fully-adjusted OR <sup>b</sup> (95% CI)	P-value	Unadjusted OR (95% CI)	P-value	Age-adjusted OR (95% CI)	P-value	Fully-adjusted OR <sup>b</sup> (95% CI)	P-value
<i>Tertiles</i>												
<i>Fruit</i>												
0-1 serve/day	1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)	
>1-2 serves/day	0.87 (0.74, 1.02)	0.09	0.87 (0.74, 1.02)	0.09	0.95 (0.80, 1.13)	0.56	0.72 (0.62, 0.83)	<0.001	0.72 (0.62, 0.84)	<0.001	0.84 (0.71, 1.0)	0.04
>2	0.90 (0.75, 1.06)	0.21	0.89 (0.75, 1.06)	0.20	0.98 (0.81, 1.17)	0.85	0.68 (0.58, 0.80)	<0.001	0.69 (0.59, 0.81)	<0.001	0.84 (0.70, 1.0)	0.06



serves/day			1.06)		1.19)		0.80)		0.81)			
Vegetables												
0-2 serves/day	1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)	
>2-4 serves/day	0.86 (0.73, 1.0)	0.05	0.85 (0.73, 1.0)	0.05	0.94 (0.79, 1.11)	0.45	0.67 (0.57, 0.78)	<0.001	0.67 (0.57, 0.78)	<0.001	0.82 (0.69, 0.98)	0.03
>4 serves/day	0.96 (0.81, 1.13)	0.59	0.95 (0.81, 1.12)	0.55	0.94 (0.78, 1.13)	0.51	0.75 (0.65, 0.87)	<0.001	0.76 (0.65, 0.88)	<0.001	0.89 (0.75, 1.05)	0.17
Fruit and vegetables												
0-4 serves/day	1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)	
>4-7 serves/day	0.88 (0.76, 1.03)	0.11	0.88 (0.76, 1.03)	0.11	0.98 (0.83, 1.16)	0.82	0.63 (0.55, 0.73)	<0.001	0.64 (0.55, 0.74)	<0.001	0.77 (0.65, 0.91)	0.002
>7 serves/day	0.96 (0.80, 1.14)	0.62	0.95 (0.79, 1.14)	0.57	0.94 (0.77, 1.15)	0.52	0.71 (0.61, 0.83)	<0.001	0.72 (0.62, 0.84)	<0.001	0.86 (0.72, 1.02)	0.09

Abbreviations: CI=confidence interval, K10=Kessler Psychological Distress Scale, OR=odds ratio.

<sup>a</sup> The total K10 score is based on a 10-item questionnaire about anxiety and depression symptoms experienced in the last four weeks.<sup>24</sup> Possible K10 scores range from 10-50 with scores≥22 indicating high-to-very-high levels of psychological distress.

<sup>b</sup> Adjusted for baseline age, sex, highest education level, marital status, household annual income, body mass index category, smoking status, alcoholic intake, physical activity levels and a history of chronic disease.

<sup>c</sup> Participants who reported having been recently treated for depression/anxiety and/or taking antidepressant medication and/or with a K10 score ≥22 (n=6,067) at baseline were excluded from longitudinal analyses.

consumption with either the prevalence or incidence of psychological distress was stronger in women, with no clear associations with the incidence of psychological distress in men.

Findings in this study are in agreement with those from a recent meta-analysis, based on seven cross-sectional and four cohort studies, which has found separate fruit and vegetable consumption to be inversely associated with the risk of depression.<sup>11</sup> Although findings from individual cross-sectional and prospective studies were mixed, in subgroup analysis by study design, the meta-analysis showed significant associations in both cross-sectional and prospective studies for fruit intake, and in prospective studies only for vegetable intake. In relation to combined fruit and vegetable consumption, several large cross-sectional studies have also demonstrated significant inverse associations with psychological wellbeing, even after accounting for multiple covariates.<sup>12-14</sup> A positive association between combined fruit and vegetable consumption and wellbeing, assessed using seven different measures of mental health, was shown in three separate data sets, which together involved 80,000 randomly selected British adults.<sup>12</sup> In a repeated cross-sectional study of 296,121 Canadians with five waves of a national, population-based survey, lower odds of depression and psychological distress were consistently associated with greater combined fruit and vegetable consumption.<sup>13</sup> Our cross-sectional findings are also in line with those from a recent population-based Swiss survey of 20,220 individuals, which found that daily recommended intake of five servings of fruit and vegetables was associated with a lower likelihood of high and moderate psychological distress.<sup>14</sup>

Our longitudinal findings add to the limited evidence base for an association between fruit and vegetable consumption and the incidence of psychological distress. Although longitudinal associations with psychological distress did not remain significant at higher levels of fruit and vegetable intake, the direction of these associations was in agreement with findings from previous studies. Among the few prospective studies which have examined the relationship between fruit and vegetable intake and the incidence of depression, mostly in similar-aged samples,<sup>15-17, 28</sup> all but one study<sup>28</sup> have shown significant protective effects of fruit<sup>15,17</sup> or both fruit and vegetables.<sup>16</sup> A recent study involving a nationally representative sample of 12,385 Australian adults surveyed over several years, reported that combined fruit and vegetable consumption was predictive of increased happiness, life satisfaction and wellbeing, with improvements observed within two years.<sup>29</sup>

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1 This study is among the first to report associations between fruit and vegetable consumption  
2 and psychological wellbeing separately for men and women. Sex was a significant effect  
3 modifier of the association between fruit and vegetable consumption and psychological distress.  
4 We found that fruit and vegetables were more protective for women than men, suggesting that  
5 women may be more responsive to the effects of fruit and vegetables. It is possible that there  
6 may be a true physiological difference between men and women, although a mechanism that  
7 could explain this difference remains unclear, or perhaps women more accurately report  
8 consumption of fruit and vegetables than men. However, these preliminary findings need to be  
9 confirmed by additional studies.

10 Future investigations should also explore the possibility of a threshold between medium and  
11 higher consumption levels. In our study, fruit and vegetable consumption at the highest levels  
12 was not protective against psychological distress in fully-adjusted models, suggesting a  
13 potential threshold effect. This was also evident in the fully-adjusted models in the cross-  
14 sectional analysis in men, and the longitudinal analysis in women. The reason for this  
15 observation is unknown. It is possible that consuming more fruits and vegetables beyond the  
16 potential threshold is no longer beneficial. However, the observed pattern of association could  
17 also be a result of residual confounding. For example, participants consuming higher amounts  
18 of fruit and vegetables may also have been consuming larger quantities of other foods which  
19 could lead to psychological distress. However, despite adjusting for BMI in our analyses, this  
20 study did not measure other potential dietary confounders. The study's findings also did not  
21 change when adjusting for BMI as a continuous variable rather than a categorical variable.  
22 Participants with very high fruit and vegetable consumption may have other unmeasured  
23 characteristics that could have offset the beneficial effects of fruit and vegetable consumption.  
24 Finally, it is important to acknowledge that fruit and vegetable consumption was based on a  
25 one-time measure only, which could not take into account long-term consumption patterns.  
26 However, as compared with baseline, we found a similar pattern of consumption at follow-up  
27 (93% of participants remained in the same consumption categories between baseline and  
28 follow-up). Some of these limitations should be addressed in future studies.

29 Although these remain to be elucidated, several mechanisms may underlie the relationship  
30 between high fruit and vegetable consumption and greater psychological wellbeing.<sup>30</sup> Fruit and  
31 vegetables are rich in micronutrients and phytochemicals that may help reduce oxidative stress  
32 and inflammation, processes that can have detrimental effects on mental health. For example,  
33 antioxidants such as vitamins C, E and polyphenols may help reduce oxidative stress while the

1 mineral magnesium has been associated with lower levels of C-reactive protein, a marker of  
2 low-grade inflammation.<sup>30</sup> Deficiencies in B-vitamins such as folic acid (vitamin B9) have been  
3 associated with depression.<sup>31</sup> Low levels of these vitamins can cause high homocysteine levels  
4 which in turn can impair methylation processes involved in the synthesis and metabolism of  
5 neurotransmitters that may affect mood.<sup>32</sup>

## 6 **Strengths and limitations**

7 This study had several strengths including a large sample size, a prospective design and the  
8 inclusion of multiple socio-demographic and lifestyle-related covariates and the use of the well-  
9 validated K10 scale to assess psychological distress. High K10 scores are strongly correlated  
10 with CIDI diagnoses of anxiety and depression.<sup>24</sup> Several study limitations should be noted. The  
11 follow-up period may have been too short to observe the full extent of long-term associations  
12 between fruit and vegetable intake and psychological distress. Although the assessment of fruit  
13 and vegetable consumption was based on short validated questions, this assessment method  
14 may be prone to reporting bias. In addition, the assessment of dietary intake was not detailed  
15 and limited to a few questions only. There may be residual confounding from unmeasured  
16 dietary confounders including total energy intake and other potential confounders such as illicit  
17 drug use a history of mental illness and unmeasured cardio-metabolic components, despite  
18 adjustment for multiple covariates. Although data was available for fish consumption, another  
19 potential dietary confounder, this variable was not included as a covariate due to the lack of  
20 variance observed ("yes/no" question for ever consumption of fish only) and adjusting for fish  
21 consumption in our analyses also did not change our results. Further, the possibility of reverse  
22 causation (i.e., that depression leads to poor diet including inadequate fruit and vegetable  
23 consumption) could not be eliminated, but was reduced by excluding participants being treated  
24 for depression/anxiety, taking anti-depressant medication or who reported high-to-very levels of  
25 psychological distress at baseline from the longitudinal analyses. Several prospective cohort  
26 studies have not found evidence for reverse causation, with diet quality related to subsequent  
27 mental health but baseline mental health not associated with subsequent diet quality.<sup>15,17,21</sup>  
28 However, a recent nationally representative longitudinal study of Canadians which explicitly  
29 tested reverse causation, showed that the association between fruit and vegetable  
30 consumption, other health behaviors and depressive symptoms are complex and bi-directional  
31 and warrants further investigation.<sup>33</sup>

## 32 **Conclusions**

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1 Fruit and vegetable consumption may help reduce the prevalence of psychological distress  
2 among middle-aged and older adults. However, the association between fruit and vegetable  
3 consumption and the incidence of psychological distress requires further investigation and  
4 possibly, a longer follow-up time. Findings from this study lend support to existing public health  
5 guidelines which encourage fruit and vegetable consumption as part of a healthy diet and add  
6 evidence to support the benefits of fruit and vegetables for mental health.

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## ACKNOWLEDGEMENTS

This research was completed using data collected through the 45 and Up Study ([www.saxinstitute.org.au/our-work/45-up-study/](http://www.saxinstitute.org.au/our-work/45-up-study/)). The 45 and Up Study is managed by the Sax Institute in collaboration with major partner Cancer Council NSW; and partners: the National Heart Foundation of Australia (NSW Division); NSW Ministry of Health; NSW Government Family and Community Services – Carers, Ageing, and Disability Inclusion; and the Australian Red Cross Blood Service. We thank the many thousands of people participating in the 45 and Up Study and the SEEF Study. The SEEF research was funded by the National Health and Medical Research Council (NHMRC) Strategic Award for Preventive Healthcare and Strengthening Australia's Social Economic Fabric (The SEEF Project; ID: 402810).

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1     **COMPETING INTERESTS**

2     The authors declare that they have no competing interests.

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## FUNDING

This research was funded from a Development Award from the Cardiovascular Research Network of NSW. BN was supported by an Australian Postgraduate Award and a University of Sydney Merit Award. DD was funded by an Early Career Fellowship from the National Health and Medical Research Council of Australia (reference number 1072223).

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**AUTHORS' CONTRIBUTIONS**

BN, DD and SM participated in the design of the study. BN carried out the statistical analyses. BN, DD and SM helped draft the manuscript. All authors helped with the interpretation of the data and revised the manuscript critically for important intellectual content. All authors read and approved the manuscript.

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- 1 **DATA SHARING STATEMENT**
- 2 No additional data are available.

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**Fig. 1. Participant flow chart**

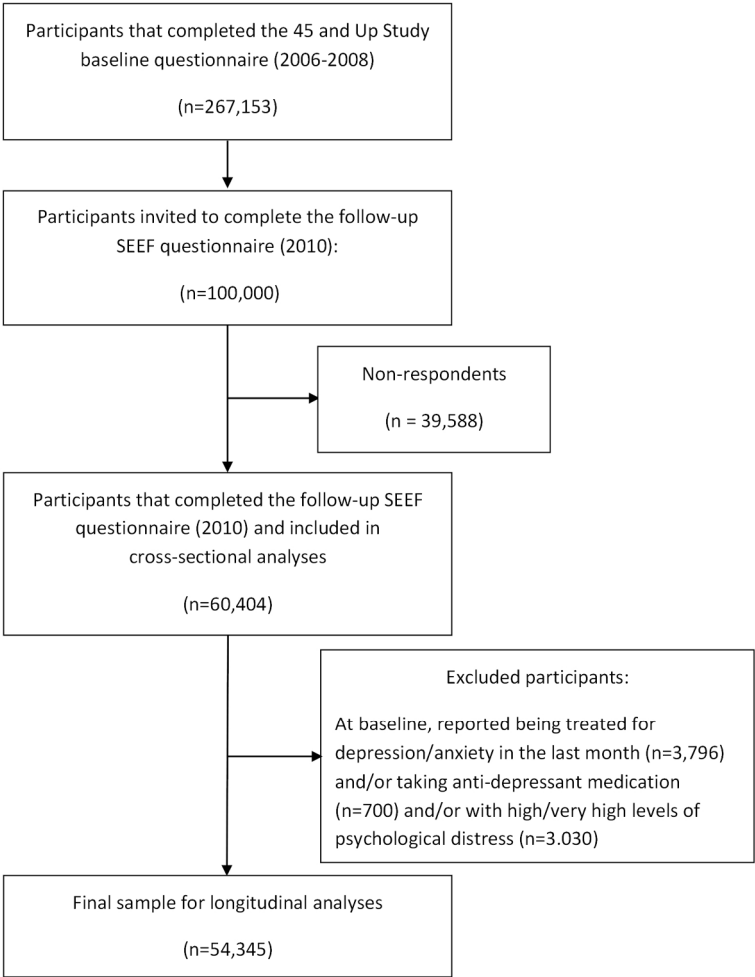


Fig. 1. Participant flow chart

173x197mm (300 x 300 DPI)

**STROBE 2007 (v4) checklist of items to be included in reports of observational studies in epidemiology\***  
**Checklist for cohort, case-control, and cross-sectional studies (combined)**

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study’s design with a commonly used term in the title or the abstract	1, 3
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5
Objectives	3	State specific objectives, including any pre-specified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(a) Cohort study—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up Case-control study—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls Cross-sectional study—Give the eligibility criteria, and the sources and methods of selection of participants	6
		(b) Cohort study—For matched studies, give matching criteria and number of exposed and unexposed Case-control study—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-8
Bias	9	Describe any efforts to address potential sources of bias	6-8
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-8
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	8
		(b) Describe any methods used to examine subgroups and interactions	8
		(c) Explain how missing data were addressed	8
		(d) Cohort study—If applicable, explain how loss to follow-up was addressed Case-control study—If applicable, explain how matching of cases and controls was addressed	



		<i>Cross-sectional study</i> —If applicable, describe analytical methods taking account of sampling strategy	
		(e) Describe any sensitivity analyses	
<b>Results</b>			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	6, Figure 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9, Table 1
		(b) Indicate number of participants with missing data for each variable of interest	8, 13-15
		(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)	9
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time	10
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure	
		<i>Cross-sectional study</i> —Report numbers of outcome events or summary measures	9
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	14-17 (Tables 2-4)
		(b) Report category boundaries when continuous variables were categorized	7-8
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9-10, 16-17
<b>Discussion</b>			
Key results	18	Summarise key results with reference to study objectives	10, 18-21
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	19-20
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	10, 18-21
Generalisability	21	Discuss the generalisability (external validity) of the study results	
<b>Other information</b>			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	24

\*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at [www.strobe-statement.org](http://www.strobe-statement.org).

# BMJ Open

## Fruit and vegetable consumption and psychological distress: cross-sectional and longitudinal analyses based on a large Australian sample

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2016-014201.R3
Article Type:	Research
Date Submitted by the Author:	23-Jan-2017
Complete List of Authors:	Nguyen, Binh; THE UNIVERSITY OF SYDNEY, Prevention Research Collaboration Ding, Ding; University of Sydney, Prevention Research Collaboration, Sydney School of Public Health Mihirshahi, Seema; THE UNIVERSITY OF SYDNEY, Prevention Research Collaboration
<b>Primary Subject Heading</b>:	Mental health
Secondary Subject Heading:	Nutrition and metabolism
Keywords:	MENTAL HEALTH, NUTRITION & DIETETICS, Depression & mood disorders < PSYCHIATRY

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## Title

# Fruit and vegetable consumption and psychological distress: cross-sectional and longitudinal analyses based on a large Australian sample

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**4 Key words**

5 Fruit, vegetable, mental health, depression

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**ABSTRACT**

**Objectives.** Growing evidence suggests a link between diet and mental health. This study aimed to investigate the association between fruit and vegetable consumption and the prevalence and incidence of psychological distress in middle-aged and older Australians.

**Design.** Cross-sectional and prospective.

**Setting.** New South Wales, Australia.

**Methods.** A sample of 60,404 adults aged  $\geq 45$  years completed baseline (2006-2008) and follow-up (2010) questionnaires. Psychological distress was assessed at baseline and follow-up using the validated Kessler psychological distress (K10) scale, a 10-item questionnaire measuring general anxiety and depression. Psychological distress was defined as the presence of high-to-very high levels of distress (K10 score  $\geq 22$ ). Usual fruit and vegetable consumption was assessed using short validated questions. The association between baseline fruit and vegetable consumption and the prevalence or incidence of psychological distress was examined using logistic regression models.

**Results.** At baseline, 5.6% reported psychological distress. After a mean 2.7 years of follow-up, 4.0% of those who did not report distress at baseline reported distress at follow-up. Baseline fruit and vegetable consumption, considered separately or combined, was associated with a lower prevalence of psychological distress even after adjustment for socio-demographic characteristics and lifestyle risk factors. Baseline fruit and vegetable consumption, measured separately or combined, was associated with a lower incidence of psychological distress in minimally-adjusted models. Most of these associations remained significant at medium levels of intake but were no longer significant at the highest intake levels in fully-adjusted models.

**Conclusions.** Increasing fruit and vegetable consumption may help reduce psychological distress in middle-aged and older adults. However, the association of fruit and vegetable consumption with the incidence of psychological distress requires further investigation, including the possibility of a threshold effect between medium and higher consumption levels.

## STRENGTHS AND LIMITATIONS OF THIS STUDY

- This study included a large sample size of 60,404 participants for cross-sectional analyses and 54,345 participants for longitudinal analyses.
- Analyses were adjusted for multiple socio-demographic and lifestyle-related covariates.
- The well-validated Kessler psychological distress (K10) scale was used to assess psychological distress.
- The relatively short follow-up time may have been insufficient to observe the full extent of long-term associations between fruit and vegetable intake and psychological distress.

1 INTRODUCTION

2 There has been a global call for action by the World Health Organisation (WHO) to make mental  
3 health a global development priority.<sup>1</sup> Mental disorders affect a tenth of the world population and  
4 represent 30% of non-fatal global burden of disease.<sup>2</sup> Depression alone is a leading cause of  
5 disability worldwide<sup>3</sup> and is projected to rank among the three leading causes of global disease  
6 burden by 2030.<sup>4</sup> There is an urgent call for public health strategies aimed at preventing the  
7 onset on common mental disorders, such as depression.

8 There has been considerable interest in the relationship between psychological wellbeing and  
9 lifestyle factors, with growing evidence for a link between mental health and diet.<sup>5-7</sup> The role of  
10 fruit and vegetables has received increasing attention, given evidence for its protective effects  
11 against chronic diseases such as cardiovascular disease and cancer.<sup>8,9</sup> Diets low in fruit have  
12 been recently identified as the leading dietary risk factor for global burden of disease.<sup>10</sup>

13 Findings from a recent meta-analysis, based on seven cross-sectional and four prospective  
14 studies, suggest that both fruit and vegetable consumption are significantly associated with a  
15 lower risk of depression.<sup>11</sup> Several large cross-sectional studies have shown that greater  
16 consumption of fruit and vegetables is associated with better mental health, including lower  
17 odds of depression and psychological distress, in the general population.<sup>12-14</sup> Fewer studies  
18 have investigated the longitudinal association between fruit and vegetable intake and  
19 depression. Higher consumption of fruit and/or vegetables was associated with lower odds of  
20 incident depression in middle-aged Australian women followed over six years,<sup>15</sup> post-  
21 menopausal American women followed for three years<sup>16</sup> and Spanish adults followed over four  
22 years.<sup>17</sup> These findings are in agreement with previous cross-sectional and longitudinal studies  
23 that have found healthy dietary patterns, including high intakes of fruit and vegetables, to be  
24 associated with a lower risk of depression and anxiety, particularly in middle-aged and older  
25 adults.<sup>18-21</sup>

26 Depression in later life is associated with increased morbidity and mortality, and decreased  
27 physical, cognitive and social functioning.<sup>22</sup> Improving mental health is an important public  
28 health challenge to address in an ageing population with a higher life expectancy.<sup>1</sup> Therefore,  
29 the main objective of this study was to investigate the association between fruit and vegetable  
30 consumption and the prevalence and incidence of psychological distress in a large cohort of  
31 middle-aged and older Australians.

## METHODS

### Study population

The baseline data were from the Sax Institute's 45 and Up Study, a large-scale (n=267,153) population study of men and women aged 45 years and over, who were randomly sampled from the general population of New South Wales (NSW), Australia. From January 2006 to December 2008, eligible individuals joined the study by completing a postal questionnaire and providing written consent for participation and long-term follow-up. The 45 and Up Study has been described in detail elsewhere.<sup>23</sup> A subsample of the 45 and Up Study was followed-up in 2010 (i.e, the Social, Economic, and Environmental Factor [SEEF] Study), with the first 100,000 participants of the 45 and Up Study invited to complete the SEEF questionnaire (60.4% response rate). A participant flow chart for this study is provided in **Figure 1**. For cross-sectional analyses at baseline, the analytic sample included 60,404 participants (53.6% women). For longitudinal analyses, participants who reported on the baseline questionnaire that they had been treated for depression/anxiety in the last month (n=3,796), and/or taking anti-depressant medication for most of the last four weeks (n=700), and/or with high/very high levels of psychological distress (n=3,030; defined as having a Kessler psychological distress scale [K10] score $\geq 22$ <sup>24</sup> were excluded (n=6,067), leaving a final sample of 54,345 participants. The 45 and Up Study was granted ethical approval by the University of NSW Human Research Ethics Committee (reference HREC 05035/HREC 10186) and the SEEF Study by the University of Sydney Human Research Ethics Committee (reference 10-2009/12187).

### Measurement

The 45 and Up Study and SEEF Study questionnaires include questions on socio-demographic characteristics, personal and medical history, and lifestyle risk factors (available from <http://www.saxinstitute.org.au/our-work/45-up-study/questionnaires/>).

### Outcome

At both baseline and follow-up, participants' general level of psychological distress was assessed using the well-validated and widely used K10 scale, a 10-item questionnaire about anxiety and depression symptoms experienced in the last four weeks.<sup>24</sup> A five-point response scale (none of the time, a little of the time, some of the time, most of the time, all of the time) is used for each item, with scores ranging from 1 (none of the time) to 5 (all of the time). Scores to each question are added up to form the total K10 score, with a possible range of 10-50. For this study, score groupings and categories of psychological distress routinely used by the Australian



1 Bureau of Statistics for national health surveys were adopted with total scores of: 10-15, 16-21,  
2 22-29 and 30-50 indicating low, moderate, high and very high levels of psychological distress,  
3 respectively.

4 High K10 scores are strongly correlated with current WHO's Composite International Diagnostic  
5 Interview (CIDI) diagnosis of anxiety and affective disorders.<sup>24</sup> Prevalence of psychological  
6 distress at baseline was defined as the presence of high-to-very high levels of psychological  
7 distress (K10 score $\geq$ 22). Incidence of psychological distress was defined as: 1) not being  
8 treated for anxiety/depression in the last month, and/or not taking anti-depressant medication for  
9 most of the last four weeks, and/or not having high/very high levels of psychological distress  
10 (K10 score $<$ 22) at baseline, and 2) the presence of high-to-very high levels of psychological  
11 distress (K10 score $\geq$ 22) at follow-up. Psychological distress was treated as binary outcome  
12 variable in the analyses (K10 score $<$ 22 vs.  $\geq$ 22; i.e. low-to-moderate vs high-to-very high levels  
13 of distress).

14 Exposure

15 Usual fruit and vegetable consumption was assessed at baseline using the following validated  
16 short questions commonly used in health monitoring and surveillance.<sup>25</sup>

- 17 1. "About how many serves of fruit do you usually have each day?" One serve of fruit was  
18 defined as one medium piece or two small pieces of fresh fruit, or one cup of diced or  
19 canned fruit pieces.
- 20 2. "About how many serves of vegetables do you usually eat each day?" One serve of  
21 vegetables was defined as half a cup of cooked vegetables (including potatoes) or one  
22 cup of raw vegetables (e.g. salad).

23 Total fruit and vegetable consumption was derived by summing the reported number of fruit and  
24 vegetables consumed daily. Fruit and vegetable consumption, considered separately and  
25 combined, was categorised into tertiles. Using quantiles ensures that the range in exposure is  
26 captured evenly across distribution categories, which facilitates comparison between different  
27 levels of fruit and vegetable consumption among the study cohort, and has been previously  
28 used in another large cohort study.<sup>16</sup>

29 Covariates

30 Covariates included baseline self-reported socio-demographic characteristics such as sex, age,  
31 highest level of education ( $\leq$ 10 years of schooling, high school/trade

apprenticeship/certificate/diploma, university degree/higher), marital status (married/living with a partner vs. single/widowed/divorced/separated), household annual income (<\$30,000, \$30,000-\$69,999, ≥\$70,000, would rather not answer this question), self-reported history of major chronic disease (cancer other than non-melanoma skin cancer, cardiovascular disease [heart disease, stroke or blood clot], diabetes or hypertension; yes vs. no) and the following lifestyle risk factors: body mass index (BMI; derived from self-reported height and weight; defined as underweight [ $<18.5 \text{ kg/m}^2$ ], normal weight [ $18.5\text{--}<25 \text{ kg/m}^2$ ], overweight/obese [ $\geq 25 \text{ kg/m}^2$ ]), alcohol intake ( $\leq 14$  or  $>14$  drinks/week), smoking status (current regular smoker vs. not currently a regular smoker) and physical activity levels (assessed using validated questions from the Active Australia Survey,<sup>26</sup> categorised as  $<150$ ,  $150\text{--}299$  and  $\geq 300$  minutes/week).

### Statistical analysis

The association between baseline fruit and vegetable consumption and the prevalence/incidence of psychological distress (K10 score  $\geq 22$ ) was examined using logistic regression models. Odds ratios (ORs) with 95% confidence intervals (CI) are presented for unadjusted, age- and sex- adjusted, and models adjusted for all covariates as described above. We tested effect modification by sex by fitting interaction terms. To examine potential sex differences, the analyses were further stratified by sex. If one out of ten responses to K10 scale questions was missing (for 3.2% and 2.8% of participants included in cross-sectional and longitudinal analyses respectively), the missing value was imputed using the mean score across the other nine questions.<sup>27</sup> If more than one response was missing, K10 scores were considered as missing. P-values  $<0.05$  were considered statistically significant. All analyses were conducted using SPSS version 22 (IBM Corp., Armonk, NY).

**RESULTS**

**Participant characteristics**

**Table 1** shows baseline participant characteristics based on K10 score at follow-up. Overall, the mean age (standard deviation [SD]) of participants was 62.2 (10.6) years, more than half (53.6%) were women, over a quarter (26%) had a university degree/higher, over three-quarters (78%) were in a married/de facto relationship, and a quarter (25.7%) reported a household annual income  $\geq$ \$70,000. The mean (SD) serves of fruit and vegetables were respectively 2.0 (1.4) and 3.9 (2.6) serves/day. The average follow-up time period was 2.7 (0.9) years. Compared with men, women were more likely to be younger, less educated, single/widowed/divorced/separated, have a lower household annual income, a lower BMI, and to consume more fruit and vegetables and less alcohol. Participants with high-to-very high levels of psychological distress (5.6%) at baseline were more likely to be women, relatively younger, less educated and have a lower household annual income. These participants were also more likely to: have a higher BMI, be a current smoker, be less physically active and have a history of chronic disease.

**Prevalence of psychological distress**

The ORs for the association between separate or combined fruit and vegetable consumption and the prevalence of high-to-very high levels of psychological distress ( $K10 \geq 22$ ) are presented in **Table 2**. Consumption of fruit and vegetables, considered separately or combined, was consistently associated with a lower prevalence of psychological distress. Following adjustment for all covariates, these associations were slightly attenuated compared with the unadjusted model but remained significant. Other covariates which were significantly associated with the prevalence of psychological distress were being relatively younger, single/divorced/widowed/separated, a current smoker, lower education, lower household annual income, lower BMI, low physical activity levels and a self-reported history of chronic disease. There was a significant interaction between combined fruit and vegetable consumption and sex ( $p=0.049$ ). When analyses were stratified by sex (**Table 4**), the association between fruit and vegetable consumption, measured separately or combined, and the prevalence of psychological distress was markedly stronger in women and was significant for all consumption tertiles ( $p \leq 0.001$ ). Among men, only those in the medium tertiles of separate fruit and vegetable consumption had significantly lower odds of psychological distress.

**Incidence of psychological distress**

After an average of 2.7 years of follow-up, 4.0% of those who did not report distress at baseline reported distress at follow-up. **Table 3** shows the association between fruit and vegetable consumption and the incidence of high-to-very high levels of psychological distress ( $K10 \geq 22$ ). Similar to cross-sectional findings, fruit and vegetable consumption, measured separately or combined, was significantly associated with a lower incidence of psychological distress in both unadjusted and minimally-adjusted models. In the fully-adjusted models, the medium tertiles of both combined fruit and vegetable consumption, and separate vegetable consumption, remained significantly associated with reduced odds of psychological distress. The association between the medium tertile of fruit consumption and the incidence of psychological distress approached significance ( $p=0.07$ ). However, the association between the highest tertile of consumption and the incidence of psychological distress did not remain significant for consumption of fruit and vegetables considered either separately or combined. Other covariates which were significantly associated with the incidence of psychological distress were being relatively younger, single/divorced/widowed/separated, a current smoker, lower education, lower household annual income, lower alcohol intake, lower BMI, low physical activity levels and a self-reported history of chronic disease. The interaction between combined fruit and vegetable consumption and sex approached significance ( $p=0.08$ ). When analyses were stratified by sex (**Table 4**), the association between fruit and vegetable consumption, considered separately or combined, and the incidence of psychological distress was stronger in women and significant for all consumption tertiles except for the highest fruit ( $p=0.06$ ), vegetable ( $p=0.17$ ), and combined fruit and vegetable tertiles ( $p=0.09$ ) in the fully-adjusted models. There was no significant association between consumption of fruit and vegetables and the incidence of psychological distress in men.

## DISCUSSION

In this large cohort of middle-aged and older Australian adults, consumption of fruit and vegetables was significantly associated with the prevalence of psychological distress even after accounting for socio-demographic characteristics and other lifestyle risk factors. The longitudinal associations with psychological distress were less consistent. The association between fruit and vegetable intake and the incidence of psychological distress was significant after accounting for age and sex. After adjustment for all possible confounders, while this association remained mostly significant at medium levels of intake, it did not remain significant at the highest levels of intake. When considered separately in each sex, the association of fruit and vegetable

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**Table 1.** Baseline characteristics of participants according to sex and K10 score at baseline (n=60,404; 2006-2010)<sup>a</sup>

Variable	All	Men	Women	K10 score at baseline <sup>b</sup>		
				<22	≥22	p-value <sup>d</sup>
Sample size	60,404	28,057	32,347	51,393	3,030	
Mean (SD) follow-up time (years)	2.67 (0.93)	2.67 (0.93)	2.68 (0.94)	2.67 (0.94)	2.72 (0.95)	0.009
Women (%)	53.6	-	-	53.3	56.2	<0.001
Mean (SD) age (years)	62.2 (10.6)	63.9 (10.7)	60.8 (10.2) <sup>c</sup>	61.6 (10.3)	58.6 (9.6)	<0.001
Highest education <sup>c</sup> (%)						<0.001
University and higher	26.2	28.0	24.7	28.3	20.0	
High school/trade apprenticeship/certificate/ Diploma	42.7	48.5	37.7	43.3	41.3	
≤10 years	31.1	23.4	37.6	28.4	68.1	
Married/living with a partner (%)	78.0	83.5	73.2 <sup>c</sup>	79.6	68.1	<0.001
Household annual income <sup>c</sup> (%)						<0.001
<\$30,000	29.5	28.5	30.4	26.7	43.4	

\$30,000-\$69,999	28.9	31.0	27.0	29.8	25.4	
≥\$70,000	25.7	29.3	22.6	28.1	16.7	
Did not specify	15.9	11.2	20.0	15.4	14.4	
BMI category <sup>c</sup> (%)						<0.001
Underweight (<18.5 kg/m <sup>2</sup> )	1.2	0.7	1.7	1.1	2.2	
Normal weight (18.5 to <25 kg/m <sup>2</sup> )	37.9	31.8	43.3	38.4	31.0	
Overweight or obese (≥25 kg/m <sup>2</sup> )	60.9	67.6	55.0	60.5	66.8	
Current smoker (%)	5.7	5.7	5.7	5.3	13.9	<0.001
Usually consumes >14 alcohol drinks/week	14.9	24.7	6.3 <sup>c</sup>	15.3	14.8	0.44
Mean (SD) fruit consumption (serves/day)	2.0 (1.4)	1.9 (1.5)	2.2 (1.4) <sup>c</sup>	2.0 (1.4)	1.9 (1.5)	<0.001
Mean (SD) vegetable consumption (serves/day)	3.9 (2.6)	3.4 (2.6)	4.4 (2.6) <sup>c</sup>	3.9 (2.6)	3.7 (2.7)	<0.001
Physical activity level (%)						<0.001
<150 minutes/week	18.9	19.2	18.8	17.5	28.0	
150 to 299 minutes/week	16.6	16.4	16.9	16.6	18.7	
≥300 minutes/week	64.4	64.5	64.4	65.9	53.4	

History of chronic disease (%)	51.8	56.5	47.8 <sup>c</sup>	50.9	54.0	<0.001
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Abbreviations: BMI=body mass index, K10=Kessler Psychological Distress Scale, SD=standard deviation.

<sup>a</sup> Data are presented as means (SD) or percentages (%).

<sup>b</sup> The total K10 score is based on a 10-item questionnaire about anxiety and depression symptoms experienced in the last four weeks.<sup>24</sup> Participants were grouped according to K10 scores and categorised as at “low-to-moderate risk” (K10<22) or at “high-to-very high risk” of psychological distress (≥22). K10 data was missing for n=5,981.

<sup>c</sup> Significantly different from men (all p<0.001).

<sup>d</sup> P-value from independent t-tests for continuous variables and from chi-square tests for categorical variables.

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**Table 2.** Unadjusted and adjusted odds ratios for the baseline association between fruit and vegetable consumption and the prevalence of high-to-very high levels of psychological distress (K10<sup>a</sup>≥22 vs. K10<sup>a</sup><22; n=60,404).

	Prevalence/ total number of cases	Unadjusted OR (95% CI)	P-value	Age and sex-adjusted OR (95% CI)	P-value	Fully-adjusted OR <sup>b</sup> (95% CI)	P-value
<i>Tertiles</i>							
Fruit <sup>c</sup>							
0-1 serve/day	1,394/21,767	1.0 (reference)		1.0 (reference)		1.0 (reference)	
>1-2 serves/day	891/19,538	0.66 (0.60, 0.72)	<0.001	0.65 (0.59, 0.71)	<0.001	0.72 (0.65, 0.80)	<0.001
>2 serves/day	753/16254	0.71 (0.65, 0.78)	<0.001	0.72 (0.65, 0.79)	<0.001	0.87 (0.79, 0.97)	0.01
Vegetables <sup>c</sup>							
0-2 serves/day	1,277/16,694	1.0 (reference)		1.0 (reference)		1.0 (reference)	
>2-4 serves/day	919/15,560	0.73 (0.66, 0.80)	<0.001	0.70 (0.64, 0.77)	<0.001	0.81 (0.73, 0.90)	<0.001
>4 serves/day	968/15,023	0.76 (0.70, 0.84)	<0.001	0.75 (0.68, 0.82)	<0.001	0.85 (0.76, 0.94)	<0.001
Fruit and vegetables <sup>c</sup>							
0-4 serves/day	1,374/22,387	1.0 (reference)		1.0 (reference)		1.0 (reference)	
>4-7 serves/day	1,068/21,750	0.73 (0.67, 0.79)	<0.001	0.70 (0.64, 0.77)	<0.001	0.82 (0.74, 0.90)	<0.001
>7 serves/day	702/14,974	0.71 (0.64, 0.78)	<0.001	0.70 (0.63, 0.77)	<0.001	0.82 (0.74, 0.92)	0.001

Abbreviations: CI=confidence interval, K10=Kessler Psychological Distress Scale, OR=odds ratio.

<sup>a</sup> The total K10 score is based on a 10-item questionnaire about anxiety and depression symptoms experienced in the last four weeks.<sup>24</sup> Possible K10 scores range from 10-50 with scores≥22 indicating high-to-very-high levels of psychological distress.

<sup>b</sup> Adjusted for baseline age, sex, highest education level, marital status, household annual income, body mass index category, smoking status, alcohol intake, physical activity levels and a history of chronic disease.

<sup>c</sup> There were missing cases for consumption of fruit (n=3,037), vegetables (n=1,190) and combined fruit and vegetables (n=1,293).



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**Table 3.** Unadjusted and adjusted odds ratios for the incidence of high-to-very high levels of psychological distress (K10<sup>a</sup>≥22) by baseline fruit and vegetable consumption (n=54,345<sup>b</sup>).

	Incident/total number of cases	Unadjusted OR (95% CI)	P-value	Age and sex-adjusted OR (95% CI)	P-value	Fully-adjusted OR <sup>c</sup> (95% CI)	P-value
<i>Tertiles</i>							
Fruit <sup>d</sup>							
0-1 serve/day	666/19,333	1.0 (reference)		1.0 (reference)		1.0 (reference)	
>1-2 serves/day	510/17,790	0.80 (0.72, 0.89)	<0.001	0.79 (0.71, 0.88)	<0.001	0.89 (0.79, 1.01)	0.07
>2 serves/day	407/14,724	0.79 (0.70, 0.88)	<0.001	0.78 (0.69, 0.87)	<0.001	0.90 (0.79, 1.03)	0.11
Vegetables <sup>d</sup>							
0-2 serves/day	641/18,898	1.0 (reference)		1.0 (reference)		1.0 (reference)	
>2-4 serves/day	486/17,281	0.77 (0.69, 0.86)	<0.001	0.76 (0.68, 0.85)	<0.001	0.88 (0.78, 0.99)	0.03
>4 serves/day	511/17,103	0.87 (0.78, 0.97)	0.01	0.85 (0.76, 0.95)	0.003	0.92 (0.81, 1.04)	0.16
Fruit and vegetables <sup>d</sup>							
0-4 serves/day	687/19,988	1.0 (reference)		1.0 (reference)		1.0 (reference)	
>4-7 serves/day	548/19,671	0.77 (0.69, 0.85)	<0.001	0.75 (0.67, 0.83)	<0.001	0.86 (0.77, 0.97)	0.01
>7 serves/day	396/13,560	0.85 (0.76, 0.95)	0.005	0.82 (0.73, 0.93)	0.001	0.90 (0.79, 1.03)	0.12

Abbreviations: CI=confidence interval, K10=Kessler Psychological Distress Scale, OR=odds ratio.

<sup>a</sup> The total K10 score is based on a 10-item questionnaire about anxiety and depression symptoms experienced in the last four weeks.<sup>24</sup> Possible K10 scores range from 10-50 with scores≥22 indicating high-to-very-high levels of psychological distress.

<sup>b</sup> Participants who reported having been recently treated for depression/anxiety and/or taking antidepressant medication and/or with a K10<sup>a</sup> score ≥22 (n=6,067) at baseline were excluded from this analysis.

<sup>c</sup> Adjusted for baseline age, sex, highest education level, marital status, household annual income, body mass index category, smoking status, alcohol intake, physical activity levels and a history of chronic disease.

<sup>d</sup> There were missing cases for consumption of fruit (n=2,498), vegetables (n=1,063) and combined fruit and vegetables (n=1,126).

**Table 4.** Adjusted odds ratios for the prevalence and incidence of high-to-very high levels of psychological distress ( $K10^a \geq 22$  vs.  $K10^a < 22$ ) by baseline fruit and vegetable consumption and stratified by sex.

	Cross-sectional analysis											
	Male						Female					
	Unadjusted OR (95% CI)	P-value	Age-adjusted OR (95% CI)	P-value	Fully-adjusted OR <sup>b</sup> (95% CI)	P-value	Unadjusted OR (95% CI)	P-value	Age-adjusted OR (95% CI)	P-value	Fully-adjusted OR <sup>b</sup> (95% CI)	P-value
<i>Tertiles</i>												
<i>Fruit</i>												
0-1 serve/day	1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)	
>1-2 serves/day	0.69 (0.59, 0.79)	<0.001	0.71 (0.61, 0.82)	<0.001	0.78 (0.67, 0.91)	0.002	0.59 (0.52, 0.66)	<0.001	0.61 (0.54, 0.69)	<0.001	0.67 (0.59, 0.77)	<0.001
>2 serves/day	0.80 (0.69, 0.93)	0.003	0.83 (0.72, 0.96)	0.02	0.99 (0.84, 1.17)	0.95	0.61 (0.54, 0.68)	<0.001	0.65 (0.57, 0.73)	<0.001	0.79 (0.69, 0.91)	0.001
<i>Vegetables</i>												
0-2 serves/day	1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)	
>2-4 serves/day	0.70 (0.61, 0.80)	<0.001	0.71 (0.62, 0.82)	<0.001	0.80 (0.69, 0.93)	0.004	0.66 (0.59, 0.75)	<0.001	0.68 (0.60, 0.77)	<0.001	0.80 (0.70, 0.92)	0.001
>4 serves/day	0.82 (0.71, 0.95)	0.007	0.88 (0.76, 1.01)	0.07	0.91 (0.78, 1.06)	0.23	0.64 (0.57, 0.72)	<0.001	0.68 (0.60, 0.77)	<0.001	0.80 (0.70, 0.92)	0.001
<i>Fruit and vegetables</i>												
0-4 serves/day	1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)	
>4-7 serves/day	0.80 (0.70, 0.91)	0.001	0.82 (0.72, 0.94)	0.003	0.92 (0.80, 1.07)	0.28	0.60 (0.53, 0.67)	<0.001	0.62 (0.55, 0.70)	<0.001	0.73 (0.64, 0.83)	<0.001
>7 serves/day	0.79 (0.67, 0.93)	0.004	0.84 (0.72, 0.99)	0.04	0.91 (0.76, 1.09)	0.30	0.57 (0.50, 0.65)	<0.001	0.61 (0.54, 0.70)	<0.001	0.75 (0.65, 0.87)	<0.001
	Longitudinal analysis <sup>c</sup>											
	Male						Female					
	Unadjusted OR (95% CI)	P-value	Age-adjusted OR (95% CI)	P-value	Fully-adjusted OR <sup>b</sup> (95% CI)	P-value	Unadjusted OR (95% CI)	P-value	Age-adjusted OR (95% CI)	P-value	Fully-adjusted OR <sup>b</sup> (95% CI)	P-value
<i>Tertiles</i>												
<i>Fruit</i>												
0-1 serve/day	1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)	
>1-2 serves/day	0.87 (0.74, 1.02)	0.09	0.87 (0.74, 1.02)	0.09	0.95 (0.80, 1.13)	0.56	0.72 (0.62, 0.83)	<0.001	0.72 (0.62, 0.84)	<0.001	0.84 (0.71, 1.0)	0.04
>2	0.90 (0.75, 1.06)	0.21	0.89 (0.75, 1.06)	0.20	0.98 (0.81, 1.17)	0.85	0.68 (0.58, 0.79)	<0.001	0.69 (0.59, 0.80)	<0.001	0.84 (0.70, 1.0)	0.06

serves/day			1.06)		1.19)		0.80)		0.81)			
Vegetables												
0-2 serves/day	1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)	
>2-4 serves/day	0.86 (0.73, 1.0)	0.05	0.85 (0.73, 1.0)	0.05	0.94 (0.79, 1.11)	0.45	0.67 (0.57, 0.78)	<0.001	0.67 (0.57, 0.78)	<0.001	0.82 (0.69, 0.98)	0.03
>4 serves/day	0.96 (0.81, 1.13)	0.59	0.95 (0.81, 1.12)	0.55	0.94 (0.78, 1.13)	0.51	0.75 (0.65, 0.87)	<0.001	0.76 (0.65, 0.88)	<0.001	0.89 (0.75, 1.05)	0.17
Fruit and vegetables												
0-4 serves/day	1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)		1.0 (reference)	
>4-7 serves/day	0.88 (0.76, 1.03)	0.11	0.88 (0.76, 1.03)	0.11	0.98 (0.83, 1.16)	0.82	0.63 (0.55, 0.73)	<0.001	0.64 (0.55, 0.74)	<0.001	0.77 (0.65, 0.91)	0.002
>7 serves/day	0.96 (0.80, 1.14)	0.62	0.95 (0.79, 1.14)	0.57	0.94 (0.77, 1.15)	0.52	0.71 (0.61, 0.83)	<0.001	0.72 (0.62, 0.84)	<0.001	0.86 (0.72, 1.02)	0.09

Abbreviations: CI=confidence interval, K10=Kessler Psychological Distress Scale, OR=odds ratio.

<sup>a</sup> The total K10 score is based on a 10-item questionnaire about anxiety and depression symptoms experienced in the last four weeks.<sup>24</sup> Possible K10 scores range from 10-50 with scores≥22 indicating high-to-very-high levels of psychological distress.

<sup>b</sup> Adjusted for baseline age, sex, highest education level, marital status, household annual income, body mass index category, smoking status, alcoholic intake, physical activity levels and a history of chronic disease.

<sup>c</sup> Participants who reported having been recently treated for depression/anxiety and/or taking antidepressant medication and/or with a K10 score ≥22 (n=6,067) at baseline were excluded from longitudinal analyses.

consumption with either the prevalence or incidence of psychological distress was stronger in women, with no clear associations with the incidence of psychological distress in men.

Findings in this study are generally in agreement with those from a recent meta-analysis, based on seven cross-sectional and four cohort studies, which has found separate fruit and vegetable consumption to be inversely associated with the risk of depression.<sup>11</sup> Although findings from individual cross-sectional and prospective studies were mixed, in subgroup analysis by study design, the meta-analysis showed significant associations in both cross-sectional and prospective studies for fruit intake, and in prospective studies only for vegetable intake. In relation to combined fruit and vegetable consumption, several large cross-sectional studies have also demonstrated significant inverse associations with psychological wellbeing, even after accounting for multiple covariates.<sup>12-14</sup> A positive association between combined fruit and vegetable consumption and wellbeing, assessed using seven different measures of mental health, was shown in three separate data sets, which together involved 80,000 randomly selected British adults.<sup>12</sup> In a repeated cross-sectional study of 296,121 Canadians with five waves of a national, population-based survey, lower odds of depression and psychological distress were consistently associated with greater combined fruit and vegetable consumption.<sup>13</sup> Our cross-sectional findings are also in line with those from a recent population-based Swiss survey of 20,220 individuals, which found that daily recommended intake of five servings of fruit and vegetables was associated with a lower likelihood of high and moderate psychological distress.<sup>14</sup>

Our longitudinal findings add to the limited evidence base for an association between fruit and vegetable consumption and the incidence of psychological distress. Although longitudinal associations with psychological distress did not remain significant at higher levels of fruit and vegetable intake, the direction of these associations was in agreement with findings from previous studies. Among the few prospective studies which have examined the relationship between fruit and vegetable intake and the incidence of depression, mostly in similar-aged samples,<sup>15-17, 28</sup> all but one study<sup>28</sup> have shown significant protective effects of fruit<sup>15,17</sup> or both fruit and vegetables.<sup>16</sup> A recent study involving a nationally representative sample of 12,385 Australian adults surveyed over several years, reported that combined fruit and vegetable consumption was predictive of increased happiness, life satisfaction and wellbeing, with improvements observed within two years.<sup>29</sup> In the case of our study, the longitudinal association between fruit and vegetable consumption and psychological distress was attenuated the most between the age and sex-adjusted model and the fully-adjusted model, suggesting confounding.

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1 This may indicate that those who consume healthy amounts of fruit and vegetables are more  
2 likely to have favourable socioeconomic status and other lifestyle risk factors (e.g., physical  
3 activity), which together contributed to lower psychological distress.

4 This study is among the first to report associations between fruit and vegetable consumption  
5 and psychological wellbeing separately for men and women. Sex was a significant effect  
6 modifier of the association between fruit and vegetable consumption and psychological distress.  
7 We found that fruit and vegetables were more protective for women than men, suggesting that  
8 women may be more responsive to the effects of fruit and vegetables. It is possible that there  
9 may be a true physiological difference between men and women, although a mechanism that  
10 could explain this difference remains unclear, or perhaps women more accurately report  
11 consumption of fruit and vegetables than men. However, these preliminary findings need to be  
12 confirmed by additional studies.

13 Future investigations should also explore the possibility of a threshold between medium and  
14 higher consumption levels. In our study, fruit and vegetable consumption at the highest levels  
15 was not protective against psychological distress in fully-adjusted models, suggesting a  
16 potential threshold effect. This was also evident in the fully-adjusted models in the cross-  
17 sectional analysis in men, and the longitudinal analysis in women. The reason for this  
18 observation is unknown. It is possible that consuming more fruits and vegetables beyond the  
19 potential threshold is no longer beneficial. However, the observed pattern of association could  
20 also be a result of residual confounding. For example, participants consuming higher amounts  
21 of fruit and vegetables may also have been consuming larger quantities of other foods which  
22 could lead to psychological distress. However, despite adjusting for BMI in our analyses, this  
23 study did not measure other potential dietary confounders. The study's findings also did not  
24 change when adjusting for BMI as a continuous variable rather than a categorical variable.  
25 Participants with very high fruit and vegetable consumption may have other unmeasured  
26 characteristics that could have offset the beneficial effects of fruit and vegetable consumption.  
27 Finally, it is important to acknowledge that fruit and vegetable consumption was based on a  
28 one-time measure only, which could not take into account long-term consumption patterns.  
29 However, as compared with baseline, we found a similar pattern of consumption at follow-up  
30 (93% of participants remained in the same consumption categories between baseline and  
31 follow-up). Some of these limitations should be addressed in future studies.

Although these remain to be elucidated, several mechanisms may underlie the relationship between high fruit and vegetable consumption and greater psychological wellbeing.<sup>30</sup> Fruit and vegetables are rich in micronutrients and phytochemicals that may help reduce oxidative stress and inflammation, processes that can have detrimental effects on mental health. For example, antioxidants such as vitamins C, E and polyphenols may help reduce oxidative stress while the mineral magnesium has been associated with lower levels of C-reactive protein, a marker of low-grade inflammation.<sup>30</sup> Deficiencies in B-vitamins such as folic acid (vitamin B9) have been associated with depression.<sup>31</sup> Low levels of these vitamins can cause high homocysteine levels which in turn can impair methylation processes involved in the synthesis and metabolism of neurotransmitters that may affect mood.<sup>32</sup>

### Strengths and limitations

This study had several strengths including a large sample size, a prospective design and the inclusion of multiple socio-demographic and lifestyle-related covariates and the use of the well-validated K10 scale to assess psychological distress. High K10 scores are strongly correlated with CIDI diagnoses of anxiety and depression.<sup>24</sup> Several study limitations should be noted. The follow-up period may have been too short to observe the full extent of long-term associations between fruit and vegetable intake and psychological distress. Although the assessment of fruit and vegetable consumption was based on short validated questions, this assessment method may be prone to reporting bias. In addition, the assessment of dietary intake was not detailed and limited to a few questions only. There may be residual confounding from unmeasured dietary confounders including total energy intake and other potential confounders such as illicit drug use, a history of mental illness and unmeasured cardio-metabolic components, despite adjustment for multiple covariates. Although data was available for fish consumption, another potential dietary confounder, this variable was not included as a covariate due to the lack of variance observed ("yes/no" question for ever consumption of fish only) and adjusting for fish consumption in our analyses also did not change our results. Further, the possibility of reverse causation (i.e., that depression leads to poor diet including inadequate fruit and vegetable consumption) could not be eliminated, but was reduced by excluding participants being treated for depression/anxiety, taking anti-depressant medication or who reported high-to-very levels of psychological distress at baseline from the longitudinal analyses. Several prospective cohort studies have not found evidence for reverse causation, with diet quality related to subsequent mental health but baseline mental health not associated with subsequent diet quality.<sup>15,17,21</sup> However, a recent nationally representative longitudinal study of Canadians which explicitly

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1 tested reverse causation, showed that the association between fruit and vegetable  
2 consumption, other health behaviors and depressive symptoms are complex and bi-directional  
3 and warrants further investigation.<sup>33</sup>

4 **Conclusions**

5 Fruit and vegetable consumption may help reduce the prevalence of psychological distress  
6 among middle-aged and older adults. However, the association between fruit and vegetable  
7 consumption and the incidence of psychological distress requires further investigation and  
8 possibly, a longer follow-up time. Fruit and vegetable consumption may help reduce  
9 psychological distress among middle-aged and older females in a cross-sectional context, but  
10 not potentially at the highest levels of intake in females over time. Consumption at medium  
11 levels of intake may help lower psychological distress in men in a cross-sectional context;  
12 however, longitudinal associations remain unclear. Although findings from this study lend  
13 support to existing public health guidelines which encourage fruit and vegetable consumption as  
14 part of a healthy diet and add evidence to support the benefits of fruit and vegetables for mental  
15 health, further research is clearly needed.

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## ACKNOWLEDGEMENTS

This research was completed using data collected through the 45 and Up Study ([www.saxinstitute.org.au](http://www.saxinstitute.org.au)). The 45 and Up Study is managed by the Sax Institute in collaboration with major partner Cancer Council NSW; and partners: the National Heart Foundation of Australia (NSW Division); NSW Ministry of Health; NSW Government Family and Community Services – Ageing, Carers and the Disability Council NSW; and the Australian Red Cross Blood Service. We thank the many thousands of people participating in the 45 and Up Study and the SEEF Study. The SEEF research was funded by the National Health and Medical Research Council (NHMRC) Strategic Award for Preventive Healthcare and Strengthening Australia's Social Economic Fabric (The SEEF Project; ID: 402810).



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1     **COMPETING INTERESTS**

2     The authors declare that they have no competing interests.

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## FUNDING

This research was funded from a Development Award from the Cardiovascular Research Network of NSW. BN was supported by an Australian Postgraduate Award and a University of Sydney Merit Award. DD was funded by an Early Career Fellowship from the National Health and Medical Research Council of Australia (reference number 1072223).

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**AUTHORS' CONTRIBUTIONS**

BN, DD and SM participated in the design of the study. BN carried out the statistical analyses. BN, DD and SM helped draft the manuscript. All authors helped with the interpretation of the data and revised the manuscript critically for important intellectual content. All authors read and approved the manuscript.

For peer review only

- 1 **DATA SHARING STATEMENT**
- 2 No additional data are available.

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**Fig. 1. Participant flow chart**



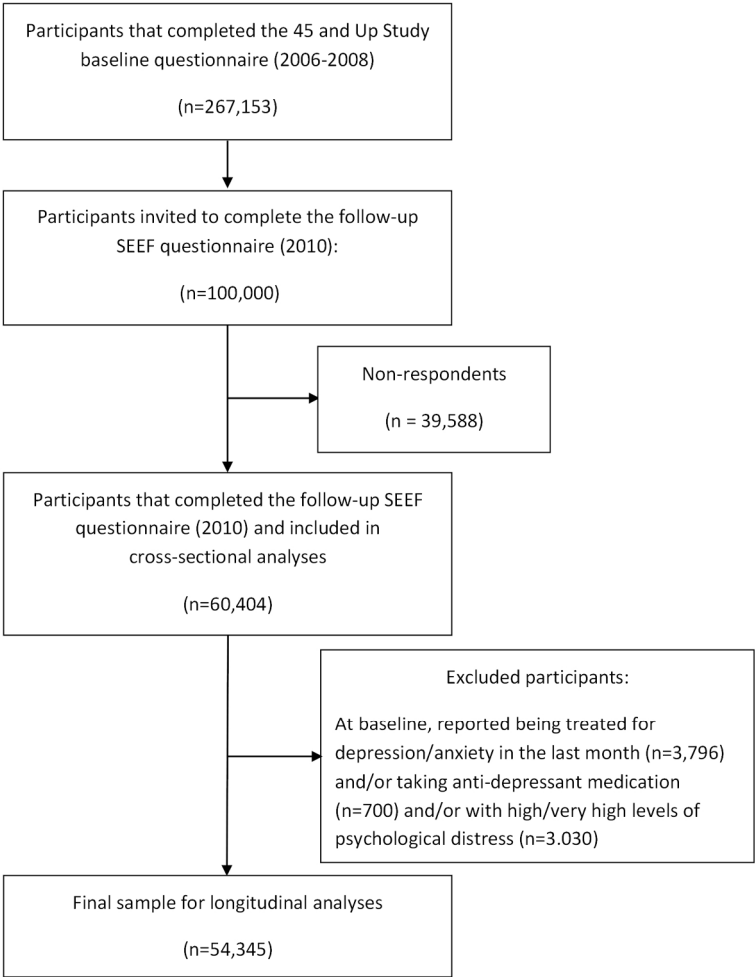


Fig. 1. Participant flow chart

173x197mm (300 x 300 DPI)

**STROBE 2007 (v4) checklist of items to be included in reports of observational studies in epidemiology\***  
**Checklist for cohort, case-control, and cross-sectional studies (combined)**

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study’s design with a commonly used term in the title or the abstract	1, 3
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5
Objectives	3	State specific objectives, including any pre-specified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(a) Cohort study—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up Case-control study—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls Cross-sectional study—Give the eligibility criteria, and the sources and methods of selection of participants	6
		(b) Cohort study—For matched studies, give matching criteria and number of exposed and unexposed Case-control study—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-8
Bias	9	Describe any efforts to address potential sources of bias	6-8
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-8
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	8
		(b) Describe any methods used to examine subgroups and interactions	8
		(c) Explain how missing data were addressed	8
		(d) Cohort study—If applicable, explain how loss to follow-up was addressed Case-control study—If applicable, explain how matching of cases and controls was addressed	

		<i>Cross-sectional study</i> —If applicable, describe analytical methods taking account of sampling strategy	
		(e) Describe any sensitivity analyses	
<b>Results</b>			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	6, Figure 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9, Table 1
		(b) Indicate number of participants with missing data for each variable of interest	8, 13-15
		(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)	9
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time	10
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure	
		<i>Cross-sectional study</i> —Report numbers of outcome events or summary measures	9
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	14-17 (Tables 2-4)
		(b) Report category boundaries when continuous variables were categorized	7-8
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9-10, 16-17
<b>Discussion</b>			
Key results	18	Summarise key results with reference to study objectives	10, 18-21
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	19-20
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	10, 18-21
Generalisability	21	Discuss the generalisability (external validity) of the study results	
<b>Other information</b>			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	24

\*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at [www.strobe-statement.org](http://www.strobe-statement.org).